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RELATIVE SUSCEPTIBILITY TO CITRUS-CANKER OF DIFFERENT SPECIES AND HYBRIDS OF THE GENUS CITRUS, INCLUDING THE WILD RELATIVES [1]

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INTRODUCTION

In a preliminary report (*6*)[3] the senior author briefly described the results obtained under greenhouse conditions for a period of six months on the susceptibility and resistance to citrus-canker of a number of plants including some of the wild relatives, Citrus fruits, and hybrids of the genus Citrus. Since that time the plants reported on have been under close observation; a third experiment has been started, and many inoculations have been made in the isolation field in southern Alabama during the summers of 1917, 1918, and 1919. Many more plants have been successfully inoculated; others have proved to be extremely susceptible; while some of those tested still show considerable resistance. The results obtained up to November 1, 1919, are described in this report.

EXPERIMENTAL METHODS

In the greenhouse, the methods used and the conditions governing the inoculations described in the preliminary report were closely followed. The same strain of the organism was used and was applied in the

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[3] Reference is made by number (italic) to "Literature cited," pp. 361–362.

same manner—that is, infusions of 48-hour-old cultures of *Pseudomonas citri* Hasse in beef bouillon were sprayed on the foliage of the plants by means of an atomizer. In no cases were punctures made, but wounds and scratches were present on some of the leaves. The plants all received identical treatments and were under approximately the same conditions.

The plants in experiment I were inoculated August 27 and September 12, 1917, and those in experiment II were inoculated October 23 and November 9. On March 23, 1918, the plants were all trimmed or cut back to force new growth, and some new numbers were placed in the screen cases together with the others. All of these were then inoculated in the usual manner. On the same date, the plants in experiment III were inoculated and have remained in the glass cases. Thus, after initial infection was obtained, natural inoculations of the remainder of the plants were counted on entirely. Therefore, natural infection took place on the greater part of the plants reported on in the following pages, especially on the more resistant plants.

In the isolation field, plantings were made in 1917, 1918, and 1919. Some of the nonhardy relatives and Citrus fruits were killed by hard winters of 1917–18 and 1918–19, but the majority of the plants survived. Inoculations in the field were started in September, 1917, by Mr. D. C. Neal and were later continued by Mr. J. Matz up to November 1, 1918, when the plants were banked for the winter. During the 1919 season the inoculations and observations in the field were made by the junior author.[1] Some of the plants were inoculated only once or twice, while others were sprayed with the inoculum regularly every week throughout the season. The time chosen for inoculation varied, but as a rule the late afternoon was chosen. A large number of natural infections took place after canker had been established on some of the plants.

The seasons of 1917 and 1918 were normal so far as climatic conditions were concerned. However, during the 1919 season the temperature was high, and together with an excessive and frequent rainfall it afforded not only ideal conditions for plant growth but also for the most rapid infection and development of canker.

Unless otherwise stated, all the plants reported on were in a good growing condition, and the organism was reisolated from the doubtful canker spots, especially in the case of the wild relatives. It must also be borne in mind that the plants used were for the most part small seedlings or nursery stock. Thus, the size of the plants and the conditions under which the inoculations were carried out made them more susceptible to canker. Plants reported here as susceptible would probably show more resistance under orchard conditions. No doubt maximum susceptibility was obtained with the plants experimented upon.

[1] The senior author is solely responsible for all conclusions drawn from the results of the three years' work.

SUSCEPTIBILITY OF NONRUTACEOUS PLANTS

Melia azedarach L., China berry, in field, 1919.

Inoculations were attempted on this plant in the field for the reason that it is the native host of the Citrus white fly. Needle prick and spray inoculations in the field under the most favorable conditions for the development of canker were negative.

Lee and Merrill (5) have reported successful inoculations of the stem and petioles of *Lansium domesticum* with *Pseudomonas citri*. This plant belongs to the same family as the China berry.

SUSCEPTIBILITY OF WILD RELATIVES OF THE GENUS CITRUS

RUTACEOUS PLANTS NOT CLOSELY RELATED TO THE GENUS CITRUS

Xanthoxylum sp. (CPB 11269, seedling), III.[1]

So far no canker spots have been found on the plants.

Casimiroa edulis Lav. and Lex. White sapote (CPB 7923, seedlings), I, II,[2] in field, 1919.[3]

At the October, 1918, readings a few nontypical spots were observed on several of the young leaves of the plant in experiment I. They occurred only at the wounds and scratches, no spots being found on the unbroken surface of the leaves. New spots have appeared from time to time, but in all cases they have occurred at wounds and remained unruptured. The spots (Pl. 57) are small (about 0.5 mm. in diameter), light colored, slightly raised, compact, and unruptured. They do not have an oily outline. No yellow zone is present. No positive infections were obtained in the field.

As there are three varieties of the white sapote being grown in California and Florida for its fruit, it is of interest to note that it can be successfully inoculated under greenhouse conditions, although it does show considerable resistance to citrus-canker.

Glycosmis pentaphylla DC. (CPB 2905, seedlings), II, III,[2] in field, 1918.

This is one of the few relatives tested which has, so far, remained immune to canker in both the greenhouse and field.

Claucena lansium Skeels. Wampi (CPB 7936, seedlings), I, II,[2] in field, 1917 and 1918.

A few small, nontypical, oily spots appeared on the leaves of the plants in both experiments. The spots are typical of those found on the wild relatives. Repeated inoculations in the field gave negative results.

Chalcas exotica Millsp. (*Murraea exotica* L.). Orange jessamine (CPB 7975A, seedlings), I, II, in field, 1917 and 1918.

During July, 1918, a few nontypical spots were observed on the young leaves of the plants in experiment II.

The spots resemble those on *Casimiroa edulis* in general appearance, except that they are somewhat larger and of a more oily character. A few new spots have developed since that time. The plants are only very weakly positive, and the period of incubation is rather long. The spots in all cases were at wounds and unruptured. In no case were positive results obtained in the field in spite of repeated inoculations.

RUTACEOUS PLANTS BELONGING TO TRIBE CITREAE

Subtribe Aeglinae (Hardshell Fruits)

Aegle marmelos Correa. Bael fruit (CPB 7983, seedlings), I, II, in field, 1918.

During the summer months these plants made a splendid growth and produced an abundance of new foliage. At the July, 1918, reading several small spots typical of

[1] Roman numerals refer to the number of the inoculation experiment in the greenhouse.

[2] Included in experiments of March 21, 1918.

[3] Date of planting in the isolation field.

those found on *Casimiroa edulis* were observed, occurring at wounds and scratches. Spots have appeared occasionally since that time, but in every case they were observed along scratches and wounds and remained unruptured. All inoculations in the field were negative even at wounds.

Aeglopsis Chevalieri Swingle. (CPB 7633 and 7772, seedlings and cuttings), II and I,[1] in field, 1918.

The plants, although producing an abundance of new growth, have remained free from canker, in both the greenhouse and field.

Chaetospermum glutinosum (Blanco) Swingle (*Limonia glutinosa*, Blanco). Tabog (CPB 7799 and 7814, seedlings), I, II and I,[1] II,[1] III, in field, 1917 and 1918.

An abundance of new foliage was produced by all the plants, and thus they have been in an excellent condition for infection. All five of the plants have developed canker. The spots first appeared in April, 1918, three weeks after the last inoculation. The spots were at first small and nontypical (Pl. 58 A), but as they increased in numbers they became more and more typical. At the last reading the percentage of infected leaves ranged from 10 to 30, and from a few small, oily, unruptured spots (Pl. 58, B) to many medium-sized, ruptured spots (Pl. 58, C). No spots have been found on the twigs.

The small, unruptured spots generally appeared at wounds or scratches and resemble those described for *Casimiroa edulis*. The more normal spots are medium-sized, of a brick color, almost flat, compact, and slightly corky. They do not break through the upper surface but appear as a flat, discolored spot. The oily outline is very indistinct around the unbroken spots, and the yellow zone is absent. Vigorous colonies of *Pseudomonas citri* were isolated from these ruptured spots.

Unfortunately these plants are very susceptible to low temperatures and have been killed in the field each season, so that no thorough test of their susceptibility has been made. However, judging from the susceptibility shown in the greenhouse, they should be successfully inoculated in the field under favorable conditions. No positive results have been obtained so far, although the plants were repeatedly inoculated during the summers of 1917 and 1918.

Balsamocitrus Dawei Stapf. (CPB 2920, on *Aeglopsis Chevalieri*), III, in field, 1917 and 1918.

This is a large tree found in the forests of east central Africa at an altitude of 2,000 to 3,000 feet. The plant, although making a rapid growth, has remained free from canker in the field and the greenhouse.

Subtribe Feroninae (Hardshell Fruits)

Feronia limonia (Corr.) Swingle (*F. elephantum* Corr.). Wood-apple (CPB 2763, seedlings), I, II, in field, 1917 and 1918.

A few oily, unruptured spots were observed at the July, 1918, reading. The spots have become more numerous and are scattered over the new foliage, especially at wounds, but remain small and unruptured. They are typical in all respects to those described for *Casimiroa edulis*. No positive results have been obtained in the field.

Feroniella lucida Swingle. Kavista Batu (CPB 7882, seedlings), I, II, in field, 1917 and 1918.

Some small, very slow-growing, oily spots are scattered over the new foliage. They resemble in all respects those found on *Feronia limonia*. Repeated inoculations in the field have been negative.

[1] Included in experiments of March 21, 1918.

SUBTRIBE LAVANGINAE

Hesperthusa crenulata Roem. Naibel (CPB 2759, seedlings), II, III, in field, 1917 and 1918.

Because the spots produced were so nontypical the susceptibility of these plants was doubted until cankers developed on the twigs and branches. The spots (Pl. 59, B) are small and nontypical, although 90 per cent of the new leaves on the plants are infected. On the twigs they are rather numerous, flat, very oily, and apparently ruptured. In the field the few spots formed on the twigs have remained unruptured, very oily, and slightly raised. On the leaves the spots are nontypical, few, and in some cases slightly ruptured.

Triphasia trifolia P. Wilson. Lime berry (CPB 2689A and 7780, seedlings), I, II, and II, in field, 1918.

The plants have remained free from canker in both the field and greenhouse.

Severinia buxifolia Ten. (CPB 2760, cuttings and seedlings), I, II, in field, 1917, 1918, and 1919.

Like Triphasia, the plants are apparently immune.

SUBTRIBE CITRINAE

Citropsis Schweinfurthii Swingle and M. Kellerman. African cherry orange (CPB 11260, seedlings), I,[1] II, in field, 1917 and 1918.

Several small spots have developed along a wound on one leaf, while several small, scattering, and unruptured spots were found on a few young leaves. The spots are typical of those found on *Casimiroa edulis*. No positive results have been obtained in the field.

Atalantia citrioides Pierre. (CPB 7534, cuttings), I, II (2 plants), III, in field, 1918.

Canker spots first appeared on the plants in experiment I in May, 1918. Since that time all plants have become infected, the spots being well distributed over the new foliage.

The spots (Pl. 59, A) are small to medium, of a brick color, round, flat, and sometimes breaking out in a corky mass. Only a slight depression is visible on the upper surface. The oily outline is very distinct, and no yellow margin is present. The spots are somewhat similar to those described for Chaetospermum, and the plants are almost as susceptible. During 1918 no positive results were obtained on the few plants in the field.

Atalantia ceylonica Oliver (*Rissoa ceylonica*, Arn.). (CPB 11225, seedling), III.

A few oily spots (Pl. 59, A, center) have been produced on all the leaves of the plant. They are present also on the twigs. The spots are identical with those described on *A. citrioides*, although the plant is slightly more susceptible.

Poncirus trifoliata (L.) Raf. (*Citrus trifoliata* L.). Trifoliate orange (Seedlings, Alabama), I, II, III, in field, 1917.

All the plants (Pl. 65, A) included in the experiments have proved to be extremely susceptible in both the field and the greenhouse. In experiment III the plant was killed outright by the heavy canker infection. Leaves, thorns, twigs, branches, and even the old wood were attacked. As a rule, all the spots on the leaves are small to medium sized and very numerous, while on the stem they are large, girdling, and corky.

Poncirus trifoliata is extremely susceptible and therefore will always be a menace to complete eradication of canker in Alabama, especially since it has been found

[1] Included in experiments of March 21, 1918.

that canker may lie dormant in the bark tissues of the old wood and overwinter for a period of six months (7).

Eremocitrus glauca (Lindl.) Swingle (*Triphasia glauca* Lindl.; *Atalantia glauca* Benth.). Australian desert kumquat (CPB 7239 and 7397, seedlings), I, II, and III, in field, 1917.

All plants have shown infection, varying with their condition. Canker (Pl. 59, D) has been observed on the leaves, thorns, twigs, and old wood. A considerable degree of susceptibility is shown; and, under favorable conditions, the species should be successfully inoculated in the field, although such attempts have proved negative so far.

Fortunella margarita (Lour.) Swingle (*Citrus margarita* Lour.). Oval kumquat (CPB 7597, seedlings), I, II, III, in field, 1918.

Fortunella crassifolia Swingle. Meiwa kumquat (CPB 11047, seedlings), I, II (2 plants), III, in field, 1917 and 1918.

Fortunella japonica (Thunb.) Swingle (*Citrus japonica* Thunb.). Round kumquat (CPB 11301, seedlings), I, III, in field, 1918.

Fortunella Hindsii (Oliver) Swingle (*Sclerostylis Hindsii* Champ., *Atalantia Hindsii* Oliver). Hongkong wild kumquat (CPB 11046C and 11046A, seedlings), I, II, III, and I,[1] in field, 1917 and 1918.

All four species of kumquats have been successfully inoculated, although in all cases with some difficulty. From the results so far obtained no one of the first three species appears to be more susceptible than the other, the amount of infection depending on the growing condition of the individual. Judging from the type and number of spots (Pl. 60, C) *Fortunella Hindsii* is the most susceptible in that the spots are ruptured and corky.

As a rule, the spots on the other three species are characterized by being small, slow-growing, scattering, very dark, compact, and unruptured (Pl. 60, A). A few slightly ruptured, corky spots have been found on the plants, but usually at wounds.

Three plants of *Fortunella Hindsii* have been successfully inoculated in the field. A few minute infections were obtained on *Fortunella margarita* and *Fortunella japonica* during August, 1919. Plants of the oval kumquat, budded on *Poncirus trifoliata*, were inoculated in the field every week during the growing season of 1918 with negative results.

Microcitrus australasica (Muell.) Swingle (*Citrus australasica*, Muell.). Finger lime (CPB 7600 and 7600B, cuttings and seedlings), I, II, III, and II, in field, 1917.

Microcitrus australasica var. **sanguinea** Swingle. (CPB 7775B, cutting), II.

Microcitrus Garrowayi (Bail.) Swingle (*Citrus Garrowayi*, Bail.). Garroway's finger lime (CPB 11008, cuttings), I, II, III.

Microcitrus australis (Planch.) Swingle (*Citrus australis*, Planch.). Dooja (CPB 7307 and 7427, cuttings and seedlings), I, II, in field, 1917.

The last two species have proved to be quite easily infected with canker, but it was not until quite recently that *Microcitrus australasica* and its variety *sanguinea* became infected. Here infection is limited to a few scattering, small, slow-growing, dark, oily spots with an occasional spot on the thorns and twigs. On *M. australis* and *M. Garrowayi* from 30 to 90 per cent of the leaves have tiny, scattering, compact spots (Pl. 59, C), which do not penetrate through the leaf. Thorn, twig, and stem infections are also severe, the spots being ruptured and of a girdling type, resembling

[1] Included in experiments of March 21, 1918.

somewhat the loose, corky spots on *Poncirus trifoliata*. During the 1919 season *M. australis* was severely infected in the field, leaves, twigs, and branches being attacked. This species has shown almost as much susceptibility as *P. trifoliata*. Some leaf and stem cankers have also developed on *M. australasica*. However, it is much more resistant than *M. australis*.

In Table I the data on the susceptibility of the wild relatives of Citrus obtained by Lee (*4*) are listed for comparison with those reported on by the senior author. Lee worked in the open under field conditions at the Lamao Experiment Station, P. I., while the senior author, using the same type of plants, carried on his inoculation experiments in the greenhouses at Auburn, Ala. None of the field results are included in the table, since with few exceptions they were of a negative nature.

TABLE I.—*Findings of Lee and Peltier on the susceptibility of the Citrus relatives to citrus-canker*

Genus and species.	Lee's results.	Peltier's results.	Remarks.
RUTACEOUS PLANTS NOT CLOSELY RELATED TO THE GENUS CITRUS.			
Xanthoxylum rhetsa	Negative	Not tested	Immune.
Xanthoxylum sp.	Not tested	Negative	Do.
Evodia ridleyei	Positive	Not tested	Leaves and stem positive.
Evodia latifolia	do	do	Stem only.
Melicope triphylla	do	do	Do.
Casimiroa edulis	Not tested	Positive	Leaves only.
Toddalia asiatica	Positive	Not tested	Leaves and stem positive.
Glycosmis pentaphylla	Not tested	Negative	Immune.
Chalcas exotica	Positive	Positive	Lee, petioles and stem weakly positive; Peltier, leaves weakly positive.
Claucena lansium	do	do	Do.
TRIBE CITREAE. Subtribe Aeglinae.			
Aegle marmelos	Negative	Positive	Leaves only.
Aeglopsis Chevalieri	Not tested	Negative	
Chaetospermum glutinosum	Positive	Positive	Susceptible.
Balsamocitrus gabonensis	Negative	Not tested	Immune.
Balsamocitrus Dawei	Not tested	Negative	Do.
Subtribe Feroninae.			
Feronia limonia	Positive	Positive	Lee, leaves and stem positive; Peltier, leaves only.
Feroniella lucida	do	do	Lee, stems only positive; Peltier, leaves only.
Subtribe Lavanginae.			
Hesperethusa crenulata	Positive	Positive	Susceptible.
Triphasia trifolia	Negative	Negative	Immune.
Paramignya longipedunculata.	Positive	Not tested	Leaves and stems positive.
Severinia buxifolia	Negative	Negative	Immune.
Subtribe Citrinae.			
Citropsis Schweinfurthii	Positive	Positive	Lee, leaves and stems positive; Peltier, leaves only positive.
Atlantia citrioides	do	do	Lee, leaves and stems positive; Peltier, leaves very easily infected.
Atalantia ceylonica	Not tested	do	Leaves and stems easily infected.
Atalantia disticha	Positive	Not tested	Leaves and stems only weakly positive.
Poncirus trifoliata	Not tested	Positive	Extremely susceptible.
Eremocitrus glauca	Positive	do	Susceptible.
Fortunella margarita	Not tested	do	Resistant.
Fortunella japonica	Positive	do	Do.
Fortunella crassifolia	Not tested	do	Do.
Fortunella Hindsii	Positive	do	Susceptible.
Microcitrus australasica	do	do	Somewhat susceptible.
Microcitrus var. *sanguinea*	Not tested	do	Do.
Microcitrus Garrowayi	do	do	Susceptible.
Microcitrus australis	Positive	do	Do.

Not only the conditions governing the inoculations but even the methods used were widely different in the two experiments. Lee (*4*) describes his method of inoculating as follows:

> In making the inoculations an infusion of the organism was painted upon the leaf blade, midrib, petiole, or stem, as the case might be, with a small camel's-hair brush, and then the tissue was punctured through the coating of infusion with a needle. The inoculated twig was maintained in a moist condition by wrapping it in paraffin paper, including with the twig also a small piece of moistened cotton.

The senior author of the present paper, on the other hand, used infusions of the canker organism, which were sprayed directly on the plants in the screened cases by means of an atomizer. In no case were punctures resorted to, although wounds and scratches were present at all times on some of the leaves. It should also be noted that natural infections took place from the more susceptible plants to the majority of the wild relatives. (See dates of inoculations, p. 340.) Natural infections could be counted on in the greenhouse cases, because the plants were set close together and intermixed, and in addition a thorough syringing with a strong water pressure was applied whenever the plants were watered. No infections occurred on any of the rather remote wild relatives of Citrus until several weeks after the last inoculation. This may be due either to the resistance of the plants and the subsequent period of accommodation of the organism to the host or to the rather extended period of incubation. The last statement appears to be more nearly correct and is substantiated by Lee's results.

Of the rutaceous plants not closely related to the genus Citrus positive infections have been obtained on *Casimiroa edulis*, *Chalcas exotica*, and *Claucena lansium*. Lee has successfully inoculated the last two plants and, in addition, *Evodia ridleyei*, *E. latifolia*, *Melicope triphylla*, and *Toddalia asiatica*. Both of us have failed to produce any infection on *Xanthoxylum* spp., while so far *Glycosmis pentaphylla* has remained immune.

Jehle (*1*, *2*) reports successful needle-prick inoculations on *Xanthoxylum fagara* (L.) Sarg. and *X. clava-hercules* (L.) Sarg. He also obtained watery swelling on *Chalcas* (*Murraea*) *exotica*. In all cases, a few nontypical, unruptured spots have been produced at wounds or scratches only. (Pl. 59.) Of the plants infected, *Chalcas exotica* responds the least, and the period of incubation is long. Lee likewise obtained only a very weak reaction.

No doubt other plants widely removed from the genus Citrus will be successfully inoculated under certain conditions, although it is extremely doubtful if any of the plants in this group will prove susceptible enough to warrant any attention except to be of interest from a scientific standpoint.

In the subtribe Aeglinae, of the tribe Citreae, *Chaetospermum glutinosum* is susceptible enough to rank with some of the Citrus fruits in

susceptibility. This confirms the observations of Lee (4) in the Philippines, where he has found Chaetospermum generally infected under field conditions. The spots (Pl. 58, C) produced on this plant are ruptured, corky, and more or less typical of those found on the plants in the genus Citrus. They occur on the leaves in the absence of wounds. *C. glutinosum* is the most distantly removed relative so far found which is quite susceptible and produces canker spots typical of those found on *Citrus* spp.

It is rather peculiar that the other plants tested in this subtribe are immune or nearly so, especially Balsamocitrus and Aeglopsis. A few small, nontypical, unruptured spots have been found on *Aegle marmelos*, but only at wounds. Thus Aegle can be classed with the first group discussed in its resistance to canker. Lee (4) failed to obtain any infection on Aegle. This is the only plant of the whole group tested by us where Lee's results and mine failed to check.

On both *Feronia limonia* and *Feroniella lucida* positive infections have been obtained. While the spots are typical of those described for the rutaceous group, they can develop in the absence of wounds on the leaves.

Of the plants tested in the subtribe Lavanginae, *Triphasia trifolia* and *Severinia buxifolia* have remained free from canker. Lee (4) has likewise failed to obtain infection on these plants after repeated trials. No doubt, both species will prove immune to canker. *Hesperthusa crenulata*, on the other hand, is quite susceptible, in fact, almost as much so as Chaetospermum. While both leaves and twigs are attacked in the absence of wounds, the spots (Pl. 59, B) do not resemble those found on any other host. They are flat, and though they rupture, there is no evidence of the corky tissue so typical of the canker spots on Citrus.

Citropsis Schweinfurthii, in the subtribe Citrinae, ranks with the rutaceous plants in susceptibility, in that infections occur only at wounds and the spots are small, nontypical, and unruptured. *Atalantia citrioides* and *A. ceylonica* have proved quite susceptible. The spots (Pl. 59, A) are medium-sized, ruptured, corky, and resemble somewhat those found on Chaetospermum. Lee reports *A. citrioides* and *A. disticha* rather resistant.

Poncirus trifoliata is without doubt the most susceptible of the wild relatives. Somewhat less susceptible is *Eremocitrus glauca*. Canker spots (Pl. 59, D) have appeared on the leaves, thorns, branches, and stems of this plant. The spots are small but ruptured and corky, while on the branches they are of a girdling type, resembling the stem cankers on *P. trifoliata*, except in size. Equally susceptible and with the same type of canker spots are *Microcitrus australis* and *M. Garrowayi*. *M. australasica* and its variety *sanguinea* are more resistant, although spots of the same type occur on the leaves, thorns, and twigs.

Of the kumquats, *Fortunella Hindsii* is susceptible. Lee (4) reports that canker occurs naturally on the wild plants on the mountains near Hongkong. The canker spots (Pl. 60, C) on *F. Hindsii* are ruptured,

raised, and corky, resembling those found on Citrus. The other three species of kumquats tested are equally resistant. While infection has been more or less general in the greenhouse on the young foliage the spots with but few exceptions have remained unruptured.

Thus, outside the subtribe Citrinae, only two susceptible plants, *Hesperthusa crenulata* and *Chaetospermum glutinosum*, have been found under greenhouse conditions. The rest of the plants which were successfully inoculated all produced nontypical, unruptured spots at wounds. To this group can be added *Citropsis Schweinfurthii*. The plants reported free from canker will probably remain immune, while other plants not tested may prove susceptible when inoculated. The remaining plants in the subtribe Citrinae have all been successfully inoculated.

In the field successful inoculation both natural and artificial have been produced on *Hesperthusa crenulata*, *Poncirus trifoliata*, *Fortunella Hindsii*, *F. margarita*, *F. japonica*, *Microcitrus australasica*, and *M. australis*. Of these *P. trifoliata* and *M. australis* are very susceptible. No doubt under favorable conditions *Atalantia citrioides*, *A. ceylonica*, *Eremocitrus glauca*, and *Chaetospermum glutinosum* can be successfully inoculated in the field. However, none of them will prove as susceptible as *P. trifoliata*.

Thus, only the relatives most susceptible under greenhouse conditions have been successfully inoculated in the field. So far as the menace of citrus-canker to the Citrus industry in the United States is concerned, with the exception of *Poncirus trifoliata*, none of the relatives, native or introduced, discussed above are susceptible enough to warrant further attention.

The index of susceptibility to citrus-canker of these plants should be based not on the ability to successfully produce canker infections through needle pricks or wounds, under abnormal conditions, but rather on the ability of the organism to gain entrance into the tissues through natural openings of the leaves in the absence of both artificial and natural wounds. Therefore, the senior author believes that even though he has been able to inoculate a large number of the wild relatives the results have no bearing on the eradication program. It is purely of scientific interest to know that *P. citri* is not limited to the genus Citrus but can produce, under certain conditions, infections on a wide range of plants in the family Rutaceae to which Citrus belongs.

The senior author has devoted considerable attention to a study of the various types of spots produced on the various hosts, hoping to be able to correlate the type of spot with resistance. In brief, the spots as observed on the relatives can be classed as follows: Small, slow growing, nontypical, unruptured spots (Pl. 57) occurring only at wounds on rutaceous plants; same type of spots, but occurring on the leaves in the absence of wounds (on *Feronia limonia*); more typical spots (Pl. 60, *A*) which are unruptured except at wounds (on *Fortunella margarita*); and typical, ruptured, corky spots (Pl. 63, D) (on *Poncirus trifoliata*.)

SUSCEPTIBILITY OF CITRUS FRUITS

Citrus hystrix DC. (CPB 7872 and 2881, seedlings), I, II, III, in field, 1917 and 1918. "Cabayao" (CPB 7831, seedlings), I, II.

Two types of these plants have been tested. One group has pointed leaves while the second has rounded ends. Very little infection has been found on the plants with the pointed leaves, either in the field or the greenhouse (Pl. 61). However, 70 to 100 per cent of the leaves having rounded tips were infected with small to large and scattering to many spots. Some defoliation occurred. Rather large spots of a girdling type are common on thorns, twigs, branches, and old wood.

Lee (*3*) finds that of the numbers tested by him in the Philippines seven were severely infected, three moderately so, one slightly, while canker was not observed on four, and one proved resistant. As the group is obscure, although a large one, some forms may be found resistant to canker. However, the majority, especially those with rounded leaves, will prove to be almost as susceptible as grapefruit.

Citrus medica L. Citron of commerce (CPB 7768 and 7836, cuttings and seedlings), I, II, and III. "Sidro" (CPB 7816, seedlings), II. "Nana" (CPB 11281, seedlings), II, III. "Odorata" (CPB 11294, seedlings), II, III. "Etrog" (CPB 11178, seedling), I,[1] II.

Of the citrons tested, the "Etrog" proved to be the most susceptible. All the leaves were infected and some defoliation occurred. Twig and stem infections were also present. A few twig and stem spots were found on CPB 7768, 7836, and 11281. On the other numbers canker was limited to the foliage, the percentage of leaf infection varying from 30 to 100, with little defoliation.

The spots were, for the most part, small and scattering and very distinct in character. No doubt the texture of the leaves has a direct influence on the type of spot produced and also on the susceptibility of the leaves. The citrons, as a whole, while rather easily infected, are not as susceptible as grapefruit but are more so than Satsuma, (*Citrus nobilis* var. *unshiu* Swingle).

Lee (*3*) tested 14 numbers in the Philippines and found 1 resistant, 5 on which canker was not observed, 5 with medium infection, and 3 severely infected. He is of the opinion that some of the citrons may be considered as canker-resistant.

Citrus sp. Small lemon (CPB 7833, seedlings), I,[1] II. Sweet lemon (CPB 1158, seedlings), I, II. "Davo lemon" (CPB 7837, seedlings), II, III. Limon real 18 (CPB 7819, seedling), II.

The plants of the lemon group so far tested have all proved more susceptible than the citrons. All the plants in the experiments have few to many large twig and stem spots, while 50 to 100 per cent of the leaves are infected. Canker also caused some defoliation of the plants.

Two types of spots are produced on the foliage. Where the texture of the leaf resembles that of the citron the same kind of spot is produced, except that it is larger. On the plants with smooth leaves the spots resemble those found on grapefruit (Pl. 62). In the scale of susceptibility, the lemons so far tested rank just below grapefruit.

Lee's results (*3*) also show that the lemons are fairly susceptible under Philippine conditions.

Citrus sp. Ichang lemon (CPB 11291 and 11204, seedlings), I, II, III, and I, II,[1] III, in field, 1918.

The Ichang lemon was not considered under the lemon group because it appears to be a natural hybrid, possibly betweeh lemon and pummelo. The plants are very susceptible, for from 30 to 100 per cent of the leaves are infected and several plants have severe twig and stem infections. All three plants in the isolation field were reported infected during September, 1918, and August, 1919. However, all spots were localized on the leaves.

[1] Included in experiments of March 21, 1918.

The spots resemble those on grapefruit leaves (Pl. 62), but the plants rank with the lemons in susceptibility to canker.

Citrus aurantifolia (Auct.) Swingle (*C. limetta* Auct., not Risso). Sour lime (CPB 7338, seedlings), I, II.

Only a small percentage of the leaves are infected with canker. The spots are also very small and scattering. No twig or stem infections have ever developed.

The spots (Pl. 60, E) resemble those on citron to some extent. However, they are smaller, more compact, less corky, and darker in color. While the plants are rather easily infected, the spots increase slowly in size and are few in number. The sour lime is much more resistant than either the citrons or lemons, almost approaching Satsuma in resistance. Lee (*3*) reports that the limes, with the possible exception of the "Tahiti," are very susceptible in the Philippines.

Citrus grandis (L.) Osbeck (*C. decumana* L.). Grapefruit (CPB 11170, 7834 and Duncan (Alabama), seedlings), I, II; I, II; and II, III. Grapefruit (Duncan budded on *Poncirus trifoliata*), I, II. Chinese pummelo (CPB 11061, seedlings), I, III. Hirado Buntan(?) pummelo (CPB 7993, seedlings), I, II. Indian pummelo (CPB 11166 and 2968A, seedlings), I, III, and I, III. Siamese pummelo (CPB 11201 and 6111, seedlings and on *C. Schweinfurthii*), I, III, and II.

With possibly two exceptions, all the grapefruit plants tested in the greenhouse have proved to be extremely susceptible. Approximately 100 per cent leaf infection occurred, with considerable defoliation. Twig and stem infections were also severe, the spots being large and of a girdling type. Several shoots have been killed by the girdling spots.

The "Hirado Buntan," reported very susceptible in the preliminary report, has stood up very well, and at the November, 1918, reading only 5 to 10 per cent of the leaves were infected, with few or no spots on the twigs. The Siamese pummelo, especially the number budded on *Citropsis Schweinfurthii*, shows some resistance to canker.

In the field, severe infections have been obtained on grapefruit seedlings (1919), grapefruit (Duncan) budded on *Poncirus trifoliata* (1917), Sullivan grapefruit (CPB 11001 and 11054) (1918), Mark's Chinese pummelo (CPB 11061, 11217F, and 11217 G) (1918), Roeding's Indian pummelo (CPB 2968A and 11166) (1918), Florida Shaddock (CPB 11255) (1918), Orangedale Chinese pummelo (CPB 11212 U) (1918), French Martin's Chinese pummelo (CPB 11213 J) (1919), and pummelo (CPB 11219 I) (1918). (See Pl. 62.)

Only slight leaf infections have been obtained on the Hirado Buntan pummelo (CPB 7993 and 11021) and recently on the Siamese pummelo (CPB 11201 and 6111) although these plants have been in the isolation field for the past two seasons and surrounded by badly infected plants.

Mr. Swingle reports that in Japan the Hirado Buntan is quite resistant, whereas Lee (*3*) states that the Siamese pummelo is the only variety of *Citrus grandis* tested by him which gives any promise of being resistant.

Citrus sinensis Osbeck (*C. Aurantium* Lour. and Auct. not Linn.). Grenadine orange (CPB 7773, seedlings), I,[1] III. Parson Brown orange (CPB 11324, seedlings), I,[1] III. "Naranja" (CPB 7929, seedlings), II, in field, 1918. Orange (CPB 66A seedlings), I,[1] III.

With the exception of a few small, scattering spots on the twigs of two plants, canker is limited to the foliage of the plants in this group. Apparently the Parson Brown orange is the most susceptible, followed by CPB 66A. The "Naranja" and Grenadine oranges are somewhat more resistant in that only a small percentage of the leaves are infected, the spots are fewer and smaller, and no twig infections are present.

[1] Included in experiments of March 21, 1918.

All the plants of this group tested in the isolation field have been successfully inoculated. The following numbers were represented: CPB 11196 Narute, CPB 11164 Temple, CPB 11028 South Carolina, CPB 11198 Japanese No. 1, and CPB 11199 Japanese No. 2. The spots in all cases resembled those found on grapefruit.

In susceptibility this group ranks just above the citrons in that twig and stem infections are of more general occurrence. Lee (*3*) has observed that the Mediterranean varieties are less susceptible than the others. This fact has also been pointed out by other investigators.

Citrus nobilis Lour. King of Siam (CPB 2105, seedlings), I, III. "Naranjita" (?) (CPB 7830, seedlings), II, III, var. *deliciosa* Swingle. Tangarine (CPB 11195, seedlings), I, III. Cleopatra tangerine (CPB 11338, seedlings), I, II, III, var. *unshiu* Swingle. Satsuma (on *Poncirus trifoliata* Alabama), II, III.

Twig infection, consisting of small, unruptured, scattering spots, is limited to one plant (Naranjita) of this group. The spots (Pl. 63, B, at left) on the leaves are small to medium-sized, and, as a rule, rather scattering. The King of Siam orange is apparently the most susceptible. The Satsuma plants are the most resistant.

The spots (Pl. 63, B) found on the plants of the *Citrus nobilis* group are very characteristic, resembling to some extent those produced on kumquats. They are of medium size, dark, raised, compact, mostly unruptured, with a distinctly oily outline and some yellow zone. Ruptured spots are only slightly corky.

Recent investigations by Tanaka (*9*) and Scott (*8*) show that there are a number of distinct strains of Satsuma in Japan, of which three have been found in Alabama. Experiments are now under way to determine the relative susceptibility and resistance of these strains under field conditions. Successful inoculations have been made in the field on Satsuma (Pl. 64) and the Cleopatra tangerine. However, these plants are not easily attacked, canker being limited to the foliage.

All the plants tested in this group are very resistant. The writers believe that under field conditions suitable for Satsuma culture, and with no interplanting of susceptible varieties, this orange can be grown with little or no loss from canker even when the disease is prevalent. From the results so far obtained all the plants of the *Citrus nobilis* group can be placed in this class. In the investigations on susceptibility and resistance any variety showing as much resistance to canker as the Satsuma has been classed as promising.

Citrus mitis Blanco. Calamondin orange (CPB 11265, 44305, and 7065 seedlings), I, II,[1] II, III, and I,[1] II,[1] III, in field, 1917, 1918, and 1919.

Scattering stem infections and some defoliation have occurred on two of the seven plants tested. From 20 to 90 per cent of the foliage of the other plants have small to large, scattering spots.

The spots (Pl. 63, E) are altogether characteristic, and for the most part are unruptured. They are round, raised, compact, and oily, somewhat like the spots described for kumquat. When ruptured the spots are flat and have very little cork.

In the field canker is limited to the foliage, and the plants are more resistant than Satsuma. Lee (*3*) also finds that in the open *Citrus mitis* is truly resistant, and he thinks that it is apparently more so than Satsuma.

Citrus sp. Kansu (Yuzu) orange (CPB 11242, seedlings), I,[1] II, III, in field, 1918 and 1919.

The Kansu orange, collected by Mr. Frank N. Meyer in north China several years ago, is considered by Dr. T. Tanaka[2] to be the same as the well-known "Yuzu" used in Japan for many years as a stock.

Under both field and greenhouse conditions the plants have proved resistant. Apparently the leaves are quite easily infected, but the spots rarely increase in size,

[1] Included in experiments of March 21, 1918.

[2] The data are unpublished.

although they commonly rupture (Pl. 60, D). The spots do not penetrate to the upper surface. The plants are much more resistant than *Poncirus trifoliata*, which the writers understand has to a large extent replaced Yuzu as stock for Satsuma in Japan. Other conditions being equal, Yuzu is to be preferred to *P. trifoliata* from the standpoint of canker susceptibility.

Citrus sp. Natsu-mikan (CPB 11184, seedlings), I, II, III, in field, 1918 and 1919.

In some ways this plant resembles the hybrids between the grapefruit and loose-skinned oranges, such as the tangerine, known in this country as tangelos.

All plants of the Natsu-mikan in the greenhouse and field have been rather severely infected. Some twig and stem infections have been found, and from 50 to 100 per cent of the leaves have medium to large and scattering to many spots. The spots, although larger and more corky, resemble those found on Satsuma. Some defoliation has taken place, due to canker.

If the Natsu-mikan is closely related to the mandarin orange it is very much more susceptible than any of the plants so far studied in this group. Lee (*3*) reports the Natsu-mikan as susceptible in the Philippines.

Citrus excelsa Wester. (CPB 11280, seedlings), I, III.

From 90 to 100 per cent of the foliage of the two plants is infected with many large spots. Some few spots on the twigs are also present. Because of the citron-like texture of the leaves, the spots resemble those on the citron, except in size. Apparently it is not quite as susceptible as grapefruit.

In the Citrus fruits, where so many species and varieties were tested with more or less varying results, it is extremely hard to classify the susceptibility of these plants, especially where so many factors must be taken into consideration. Probably the most important and vexing factor is the physiological condition of the plant. In looking over the notes taken approximately each month on the plants in the experiments, it is found that there are certain cycles of canker infection which coincide with the growth periods of the plants. Thus, one or two observations on inoculated plants in the greenhouse or on those exposed to natural infection in the field are not sufficient to determine accurately the exact susceptibility or resistance of a plant. Some of the points to be reckoned with under the factor of the physiological condition of the plant are the rate of growth, not only of the plant but of the leaves themselves, age and size of the plant and leaves, leaf texture, and rate of maturation of the leaves. All these have an important relation to canker susceptibility and resistance.

Leaf texture with its various ramifications probably plays an important rôle in determining resistance in many cases. This can be best illustrated by comparing an infected kumquat leaf (Pl. 60, A) with an old grapefruit leaf (Pl. 60, B). The leaves are apparently very similar in texture, and a close study of the spots produced on the two shows that they are identical. In other words, while an ordinary grapefruit leaf is still thin and light green in color, it is very susceptible, large corky spots being produced. However, if an old leaf is taken which has apparently the same texture as a leaf of the kumquat, it is as hard to infect as the kumquat, and small, rounded, glistening spots are formed.

When no twig or stem infection occurs and only small, scattering, unruptured spots appear on the leaves, the plants show enough resistance to be classed as resistant. An intermediate group can be formed where the spots are larger, ruptured, and more general on the leaves, with occasional twig and stem infections. Plants placed in this group might be found promising under certain conditions. Plants which show large, ruptured spots on the leaves, severe enough to cause defoliation, and large girdling cankers on the twigs and stem should be classed as extremely susceptible. With these remarks in mind, the writers will attempt to rank the Citrus fruits, provisionally, in groups according to their susceptibility to citrus-canker.

The plants of the grapefruit and pummelo group are extremely susceptible. However, the Siamese and possibly the Hirado Buntan pummelos give promise of showing some resistance to canker.

Of the numbers tested belonging to *Citrus hystrix*, those with rounded leaves are as susceptible as grapefruit. The plants with pointed leaves are apparently more resistant to canker. More study is needed to determine whether this will hold for all forms of *Citrus hystrix* in the Philippines.

All numbers of the lemons tested, including the Ichang lemon, show about equal susceptibility, which is slightly less than that of grapefruit.

The plants of the sweet-orange group vary somewhat in susceptibility. Leaf infections are severe, and twig and stem cankers are common. As a whole, they are not as susceptible as the lemons.

Citrus excelsa and the Natsu-mikan are equally as susceptible as the plants of the sweet orange group.

Since only one number of the limes was tested, the position which the limes should take in the scale of susceptibility is doubtful. The sour lime tested proved to be somewhat resistant. However, Lee finds that with one exception the limes are susceptible.

While the citrons tested are easily infected, the spots are small, increasing very slowly in size. Twig infection occurs only occasionally and is the exception rather than the rule.

Citrus mitis, at least seedling plants such as were used in the inoculation experiments in the greenhouse, while showing some resistance are more susceptible than in the field. Leaf infections are scattering, and twig cankers are rarely produced.

The Kansu (Yuzu) orange so far has proved decidedly resistant. No twig cankers have occurred, and only small, scattering spots have developed on the foliage.

All numbers of the *Citrus nobilis* group tested have proved to be decidedly resistant, and, no doubt, all of these plants, if not mixed with susceptible varieties, could be grown under canker conditions. That does not mean that it would be economical or at all advisable to allow canker to persist even in unmixed plantings of Satsuma or other varieties of *C. nobilis*.

Faustrime[1] (*Citrus aurantifolia*, West Indian lime, × *Microcitrus australasica*). (CPB 49819, 49823, and 49835, cuttings), II; II and III.

Faustrimon (*Citrus limonia*, lemon, × *Microcitrus australasica*). (CPB 49841, 49843, and 49844, cuttings), II; II and III.

Faustrimedin (*Citrus mitis*, calamondin, × *Microcitrus australasica*). (CPB 47431, cuttings), I, III, in field, 1918.

From 30 to 90 per cent of the foliage of these plants is infected with scattering spots (Pl. 63, A). Some defoliation from canker has taken place. Thorn, twig, and stem cankers are common (Pl. 63, A). The spots are similar to those found on *Microcitrus australasica*, except that they are larger and more ruptured. The spots on the twigs and stem are of a girdling nature. The last number has been tested in the field with positive results on the foliage only. These hybrids are more susceptible than *M. australasica*.

Citrange (*Poncirus trifoliata*, × *Citrus sinensis*). Seedlings.

Two or more plants of each number of the following citranges have been given a thorough test in both the greenhouse and the field: Colman (CPB 7896 and 772 AC), Rusk (CPB 7956, 11030, 7895, and 716), Rustic (CPB 7934 A), Sanford (CPB 7963 and 1423 AB), Savage (CPB 7961 and 1423 AB), Willits (CPB 7897 B, 7960, and 777 AB), Etonia (CPB 749 AB), and citranges (CPB 1425 AB, 1416, 43931, 43480, and 43434).

The percentage of leaf infection has varied from 10 to 100 per cent, depending on the condition of the plant. The majority showed over 50 per cent of infected leaves. Defoliation of the leaves due to canker was common. Large girdling spots have appeared on the stems of most of the plants. The spots (Pl. 63, D) on the leaves and twigs are similar to those produced on *Poncirus trifoliata*.

While some variations have occurred in the susceptibility of the different numbers, the results as a whole show that all the citranges (Pl. 65, B) are equally as susceptible as *Poncirus trifoliata* (Pl. 65, B). Thus none of the citranges tested are of any promise in the search for a resistant stock.

Citrumelo (*Citrus grandis*, Bowen grapefruit, × *Poncirus trifoliata*). (CPB 4493, 4554, 4564, and 4475, seedlings), I, II; I, II (2 plants); I and I, III.

Almost 100 per cent leaf infection, with some defoliation, occurred on all the plants. The spots (Pl. 63, D) are large, scattering to many, and resemble those produced on *Poncirus trifoliata* except in size. Girdling spots of various sizes occurred on most of the plants, not only on the twigs and branches but even on the old wood.

The citrumelos (Pl. 65, C) are even more susceptible than *Poncirus trifoliata* and, therefore, are of no economic value from the standpoint of their behavior to citrus-canker.

Citradia (*Poncirus trifoliata*, × *Citrus aurantium*, sour orange). (CPB 50850, seedlings), I, II.

While from 40 to 80 per cent of the leaves have been infected with small, scattering, typical spots, no spots have been produced on the twigs or branches. Apparently, the citradia (Pl. 65, D) is a slower grower than the rest of the *Poncirus trifoliata* hybrids. The susceptibility of these plants, however, is sufficient to bar them from further tests.

Citrandarin (*Citrus nobilis* × *Poncirus trifoliata*). Seedlings.

In the greenhouse, plants of the following numbers have been given a thorough trial. CPB 40210, 40303, 40315, 40368 B, and 48529. All of these numbers are hybrids

[1] The hybrids were supplied by Mr. Walter T. Swingle, who informs me that they were labeled with the aboratory names, for the most part still unpublished. Citrange, limequat, and tangelo have been published, but citrunshu, cicitrange, citrumelo, citradia, citrandarin, faustrime, faustrimon, faustrimedin, citrangedin, citrangarin, citranguma, citrangequat, limelo, bigaraldin, orangelo, orangequat, clemelo, siamelo, satsumelo, siamor, calarin, and calashu are tentative laboratory names that may not be used in the reports which may later be issued concerning hybrids. Many hybrids which in this paper are given separate names will in later reports be grouped under some one name.

of the King of Siam orange with *Poncirus trifoliata*. In the field, CPB numbers 40175 A, 49720, 49721, 49722, 49724, and 49726 (cross between King of Siam orange and *Poncirus trifoliata*), 49624, 49625, 49629, 49644, 49663, and 49644 (cross between Clementine orange and *P. trifoliata*), 49686, 49688, 49695, 49699, and 49712 (cross between Oneco tangerine and *P. trifoliata*), 49732, 49735, 49737, 49746, and 49748 (cross between a tangerine and *P. trifoliata*) were tested.

Some individual variation in susceptibility due to the condition of the plants occurred in the greenhouse. However, all plants proved susceptible. From 30 to 100 per cent leaf infection, with some defoliation, was observed on the majority of the plants. Some scattering twig infections occurred on all but one number. Rather large, girdling spots on the old wood were found on several of the plants.

In the isolation field, all the plants have been successfully infected. An abundance of spots occurred not only on the leaves but on the twigs, branches, and old wood. No differences were noted in the susceptibility of the plants having different *Citrus nobilis* varieties as one parent. The *Poncirus trifoliata* blood predominates, in that all the leaves of the above numbers are like this plant and all have the same leaf texture. All the citrandarins (Pl. 65, E) are about as susceptible as their parent, *P. trifoliata*.

Citrunshu (*Citrus nobilis* var. *unshiu*, Satsuma, × *Poncirus trifoliata*). Seedlings and on *P. trifoliata*.

These plants are very similar to the citrandarins, and their behavior towards citrus-canker is likewise the same. Of the nine numbers (CPB 51102, 49607, 49608, 49611, 49615, 49616, 49619, 49620, and 49623) tested in the field, all proved equally susceptible. Leaf infection was common, and some stem cankers were present. They are more resistant than the citrandarins, although further tests may show them to be as susceptible. The type of spot produced on all these plants is identical to those on *Poncirus trifoliata*.

Cicitrange (*Poncirus trifoliata* × Colman citrange, and *P. trifoliata* × Sanford citrange). (CPB 48290 and 48316A, seedlings), I, II, and I, II, III.

These plants have shown considerable susceptibility to canker throughout the course of the inoculation experiments; in fact, one plant was killed by canker, while the others have been severely attacked. Without question, the cicitranges (Pl. 65, F) are equally as susceptible as *Poncirus trifoliata*.

Citrangedin (a citrange × *Citrus mitis*, calamondin). Seedlings and on *Poncirus trifoliata*.

All plants in the greenhouse (CPB 48045) and isolation field (CPB 50485, 50486, 50493, 50495, 50500, and 50501) have been successfully infected. The spots are rather small and scattering on the leaves. Few twig and stem cankers have been observed. The spots are not typical of those produced on the citranges but resemble more those on *Citrus mitis*. The fact that these plants are more resistant to canker and that the spots themselves are not similar to those on the citranges can be traced back primarily to a difference in the leaf texture of the two hybrids. The citrangedins are more susceptible than *C. mitis*, but they are more resistant than the citranges. While the leaves still retain their trifoliate character, the size, shape, and texture of the leaflets are different. They are also a darker green, and apparently mature faster than the leaves of the citranges.

Citrangarin (Sanford citrange × *Citrus nobilis* var. *deliciosa*, Oneco tangerine). Seedlings.

A plant (CPB 48776) of this hybrid was tested in the isolation field and has been successfully infected with a few scattering spots resembling those on Satsuma. While the leaves of this plant are trifoliate, they have a texture similar to that of the

tangerine. It is interesting to compare the susceptibility of the citrangarin and the citrandarin. The latter was found to be as susceptible as *Poncirus trifoliata* and was very similar in character. The citrangarin, on the other hand, while it retains the trifoliate character, has a leaf texture more like the second parent and is much more resistant.

Citranguma (*Citrus nobilis* var. *unshiu*, Satsuma, × Morton citrange). Seedlings.

The citranguma (Pl. 65, G) is possibly slightly more susceptible than the Satsuma. Leaf infections have been secured in both the greenhouse (CPB 48055, and 48055A) and field (CPB 49773). An occasional spot has been found on the smaller twigs of these plants in the greenhouse and field.

The leaf texture and type of spot are similar to those found on the Satsuma. However, the leaves do not reach maturity so soon. There is a decided tendency in the citranguma plants for the leaves to revert from the trifoliate to a single leaf. This is especially noticeable on the new growth.

Citrangequat (Willits citrange × *Fortunella margarita*, oval kumquat). Seedlings.

The citrangequat, without question, is the most promising hybrid so far tested. No natural infections have ever been obtained in the field (CPB 48010E and 48010F). Under greenhouse conditions (CPB 48010 and 48010D) only several tender leaves have been infected with tiny, compact, unruptured spots (Pl. 63, C). So far, the citrangequat has shown more resistance than any of its parents.

These plants (Pl. 65, H) make a splendid, rapid, straight growth. The rate of growth is more rapid than that of *Poncirus trifoliata*, and the plants are much better adapted for budding purposes. The trifoliate leaves are rather small and retain considerable of the leaf texture of the kumquat. The maturation of the leaves is also as rapid as in the kumquat. The leaves, especially those on the new growth, have a tendency to revert to the signle leaf of the kumquat.

Limequat (*Citrus aurantifolia*, West Indian lime, × *Fortunella japonica*, round kumquat). Seedlings.

All plants in the greenhouse (CPB 48787A, 48787B, 49787E, 49792E, and 48798E) and isolation field (CPB 48792E) have been infected. Leaf, twig, thorn, branch, and stem spots are common. In fact the limequat is more susceptible than either parent.

Several plants have died in the greenhouse experiments from overwatering, although plants next to them have thrived. On the whole, the limequat plants (Pl. 66, B) worked with have not been strong nor altogether healthy. The rate of growth of these plants has also been slow. It may be that strong, healthy plants growing under ideal conditions would show more resistance to canker. However, judging from the results obtained with the plants available, the limequat is somewhat susceptible.

Limelo (*Citrus aurantifolia*, West Indian lime, × *C. grandis*, sour pummelo). (CPB 40502, 40526A, and 40567B, seedlings), I, II; I, III, and I, II.

All limelos (Pl. 66, A) tested have proved to be equally as susceptible as grapefruit, so that they are of no practical importance from their ability to resist canker under orchard conditions.

Bigaraldin (*Citrus aurantium*, sour orange, × *C. mitis*, calamondin). On *Poncirus trifoliata*.

Only one plant (CPB 50352) of this hybrid was included in the field. It was successfully infected and no doubt will prove as susceptible as the sour orange.

Orangelo (*Citrus grandis*, Bowen grapefruit, × *C. sinensis*, Lamb summer orange). Seedlings.

All three plants (CPB 1668A) in the isolation field have been successfully infected. Spots are limited to the leaves. No twig or stem cankers have developed. Judging from the type of spot produced and the leaf texture, this hybrid will prove rather susceptible.

Orangequat (*Citrus sinensis*, Hartley mandarin, × *Fortunella margarita*, oval kumquat). On *Poncirus trifoliata*.

The one plant (CPB 50312) in the isolation field was easily infected. A few twig and stem cankers have appeared. Judging from the leaf texture and type of spot, it may prove susceptible.

Clemelo (*Citrus nobilis*, Clementine orange, × *C. grandis*, grapefruit). On *Poncirus trifoliata*.

Both the plants in the greenhouse (CPB 49006, 49012, 49013, 49025, and 49038) and those in the field (CPB 49029, 49032, and 49049) have been easily infected. From 50 to 100 per cent leaf infection with some defoliation has occurred. Most of the plants in the greenhouse have large, girdling stem cankers. The spots in all cases resemble those on grapefruit. The clemelos (Pl. 67, B, at left) are as susceptible as grapefruit and therefore can not be considered promising.

Siamelo (*Citrus nobilis*, King of Siam orange, × *C. grandis*, grapefruit). Seedlings and on *C. grandis*.

The behavior of the siamelos (Pl. 67, A) (CPB 47255B, 51588, 51598, 59852, 52007N2, 52013S9, and 52021A5) in the greenhouse, and 50320, 52007N2, 52007B3, and 51947 in the field, toward canker is about like that of the clemelos. However, they are not quite as susceptible, in that less twig and stem infections occurred.

Satsumelo (*Citrus nobilis* var. *unshiu*, Satsuma, × *C. grandis*, grapefruit.) On *Poncirus trifoliata* and *C. grandis*.

Many numbers of this hybrid have been tested in the field (CPB 50304) and greenhouse (CPB 50304, 52009A 2, 52009G 5, 52011, and 52011G 4). Thus far, the satsumelos react to citrus-canker in the same manner and extent as the siamelos (Pl. 67, B, center).

Siamor (*Citrus nobilis*, King of Siam orange, × *C. sinensis*. (CPB 52029E 2, seedling), III.

The plant included in the greenhouse experiment has proved to be extremely susceptible to canker. Heavy defoliation and severe stem cankers occurred soon after inoculation. Leaf texture and the type of spot are identical with those of grapefruit. The plant is likewise as susceptible.

Tangelo (*Citrus nobilis* var. *deliciosa*, tangerine, × *C. grandis*, Florida grapefruit). Seedlings, and on *C. grandis*.

Besides the Thornton (CPB L715, and 11034 greenhouse and L714B field) and Sampson (CPB L789A and 7664 greenhouse, and 7664 and 11037 field) tangelos, which are now being grown to a small extent in Florida, about a dozen numbers (CPB 1230, 1257A, L16, 7161, 7675C, 1191, 1348A, 1262B, 40971A, 52018C2, and 52018E2 in the greenhouse and CPB 52016E4 in the field) were tested. Plants of all numbers have been infected. From 20 to 100 per cent leaf infection has occurred in the greenhouse. Twigs and stem infections have not been general but are rather the exception than the rule. In the field, canker has been limited to the foliage. The spots in all cases resemble those on grapefruit. Careful observations have shown that those plants (Pl. 68, B) with leaves resembling the tangerine are more resistant than the numbers with grapefruit leaves. For the present the tangelos can be considered somewhat promising but not quite so resistant as the Satsuma.

Calarin (*Citrus mitis*, calamondin, × *C. nobilis* var. *deliciosa*, tangerine). On *Poncirus trifoliata.*

The one plant (CPB 50314) tested proved to be easily infected in the field. However, no twig or stem spots have been observed. Further trials are necessary before the susceptibility of the plant can be definitely judged.

Calashu (*Citrus mitis*, calamondin, × *C. nobilis* var. *unshiu*, Satsuma.) On *Poncirus trifoliata.*

The plant (CPB 50309) in the isolation field has reacted to canker in about the same degree as the calarin.

Among the numerous crosses of Citrus fruits made by Mr. Swingle *Poncirus trifoliata* was used as one parent in the hope of obtaining hybrids more resistant to low temperatures than the ordinary Citrus fruits. Thus, *P. trifoliata* has been crossed with sweet orange, sour orange, grapefruit, King of Siam orange, tangerine, Clementine orange, Satsuma, and citrange. While all of the resulting hybrids have proved to be quite resistant to low temperatures they are equally as susceptible to citrus-canker as *P. trifoliata*; in fact, the citrumelos are even more so. The hybrids all resemble *P. trifoliata* in size, shape, and texture of leaves, so that the more or less resistant mandarin group has had no influence on the character or resistance of the hybrid. Thus, it can be safely predicted that all crosses with *P. trifoliata* will yield a hardy hybrid resembling *P. trifoliata* and equally susceptible.

On the other hand, the citranges, while equally as susceptible as *Poncirus trifoliata*, when crossed with calamondin, tangerine, Satsuma, and kumquat, yield hybrids which are hardy and at the same time resistant to citrus-canker. In fact, the citrangequat is even more resistant than the kumquats themselves, in spite of the fact that it is a rather rank and rapid grower. The citrangarins and citranguma, while not as resistant as the citrangequat, are decidedly more resistant than the citrandarin and citrunshu, the corresponding hybrids with *P. trifoliata.*

These hybrids, while still retaining the trifoliate character of *Poncirus trifoliata*, are more like the resistant parent in texture of the leaves. In the case of the citranguma and citrangequats there is also a tendency for the leaves to revert to a single leaf. Thus, any plant resistant to canker when crossed with the citranges will be hardy and resistant, or even more so than the original resistant parent, as shown by the behavior of the citrangequat, even though the citranges are equally as susceptible to canker as *P. trifoliata.*

The limequat and the orangequat, while more resistant than the lime or orange, are not as resistant to canker as the kumquat. The leaves resemble those of lime and orange, respectively, in size and shape, but the leaf texture resembles more that of the kumquat. The citrangequat is much more resistant to canker that the two hybrids named above, in spite of the fact that the citrange is much more susceptible than either the lime or orange.

The influence of pummelo on the second parent varies. As is to be expected, pummelo crossed with lime and orange produced hybrids which are as susceptible as grapefruit. Hybrids between pummelo and Clementine orange, King of Siam orange, tangerine, and Satsuma are susceptible to some extent, variation in susceptibility depending more or less on whether the leaf is of the grapefruit or the mandarin type.

The calarin, hybrid between calamondin and tangerine, and the calasshu, hybrid between calamondin and Satsuma, so far give promise of being as resistant as their parents.

FALSE HYBRIDS

A rather large number of "false hybrids" or nucellar bud sports, the the results of Mr. Swingle's crosses with varieties of Chinese pummelo and American grapefruit were tested in both the field and the greenhouse. The plants were vigorous growers and produced abundance of new growth. Most of these false hybrids resemble the Chinese pummelo.

All proved extremely susceptible, in fact, even more so than grapefruit (Pl. 68, A). Leaf infections were so severe as to cause defoliation. The spots on the twigs and stems were large and of a girdling nature. A number of twigs and several plants were killed outright by complete girdling. The spots in all cases resembled those found on grapefruit. Thus, all the false hybrids tested are extremely susceptible in both the field and the greenhouse, and no one of them gives any promise of canker resistance.

SUMMARY

(1) The investigations on the susceptibility and resistance to *Pseudomonas citri* Hasse of the wild relatives, Citrus fruits, and hybrids of the genus Citrus reported on in a preliminary paper have been continued in both the field and greenhouse. Many more numbers have been successfully inoculated, others have proved to be extremely susceptible, while some still show considerable resistance.

(2) The successful inoculation of a large number of wild relatives in the greenhouse shows that *Pseudomonas citri* has a wide range of hosts and is not limited to the genus Citrus.

(*a*) Of the rutaceous plants not closely related to Citrus, positive infections have been obtained on *Casimiroa edulis*, *Chalcas exotica*, and *Claucena lansium*. *Xanthoxylum* sp., and *Glycosmis pentaphylla* have remained immune. In all cases a few nontypical, unruptured spots have been produced, but only at wounds or scratches on the leaves. *Chalcas exotica* responded the least, and the period of incubation was long.

(*b*) Of the tribe Citreae, subtribe Aeglinae, *Chaetospermum glutinosum* is the most distantly removed relative, so far found, that is quite susceptible and on which canker spots are more like those found on Citrus. *Aegle marmelos* has been only slightly infected, while *Balsamocitrus Dawei* and *Aeglopsis Chevalieri* have remained immune.

(*c*) Both *Feronia limonia* and *Feroniella lucida* of the subtribe Feroninae have been successfully inoculated. While the spots are typical of those described for the rutaceous group, they can develop in the absence of wounds.

(*d*) Of the plants tested in the subtribe Lavanginae, *Hesperthusa crenulata*, while producing very nontypical spots, is quite susceptible in that infection can take place on the leaves and twigs. *Triphasia trifolia* and *Severinia buxifolia* have remained immune.

(*e*) All plants of the subtribe Citrinae which have been tested have been infected. *Citropsis Schweinfurthii* is weakly positive; *Atalantia citrioides* and *A. ceylonica* are easily infected; *Eremocitrus glauca*, *Microcitrus australasica*, *M. australasica* var. *sanguinea*, *M. australis* and *M. Garrowayi*, plants native to Australia, are rather susceptible in that leaves, twigs, thorns, and branches are attacked; all four species of kumquat have been successfully infected; *Fortunella margarita*, *F. japonica*, and *F. crassifolia* exhibited considerable resistance, while *F. Hindsii* is very susceptible; and *Poncirus trifoliata* is extremely susceptible.

(*f*) Although working under entirely different conditions and using different methods of inoculating plants, Lee's results with the wild relatives check with those obtained by the senior author in the greenhouse, with one exception.

(*g*) In the field, only the wild relatives which were most susceptible under greenhouse conditions have been successfully inoculated. Of these *Poncirus trifoliata* and *Microcitrus australis* have proved to be susceptible, while *M. australasica* and *Fortunella Hindsii* are somewhat susceptible. *Hesperthusa crenulata* reacts to canker in about the same degree in the field as in the greenhouse.

(*h*) So far as the menace of citrus-canker to the Citrus industry of the United States is concerned, with the exception of *Poncirus trifoliata*, none of the wild relatives, native or introduced, now growing in the Citrus districts are susceptible enough to have any bearing on the eradication program.

(3) Little or no change in the susceptibility or resistance to citrus-canker has been noted among the Citrus fruits from that previously indicated. All plants tested have been successfully inoculated.

(*a*) The plants of the grapefruit and pummelo group are extremely susceptible, with the exception of the Hirado Buntan and Siamese pummelos.

(*b*) Of the numbers tested belonging to *Citrus hystrix*, those with rounded leaves are as susceptible as grapefruit. The plants with pointed leaves are apparently more resistant.

(*c*) All numbers of lemons tested, including the Ichang lemon, show about equal susceptibility, which is slightly less than that for grapefruit.

(*d*) As a whole, the plants of the sweet-orange group are slightly less susceptible than the lemons. *Citrus excelsa* and the Natsu-mikan can be classed with the sweet orange in susceptibility.

(*e*) The sour lime tested proved to be somewhat resistant.

(*f*) While the citrons are easily infected, the spots are small and increase slowly in size. Twig infection is not common.

(*g*) *Citrus mitis*, while showing some resistance, is more susceptible than has been reported from the Philippines.

(*h*) The Kansu (Yuzu) orange has proved somewhat resistant. No twig infection has occurred, and only scattering spots have developed on the foliage.

(*i*) All numbers of *Citrus nobilis* and its varieties have proved to be rather resistant to canker.

(4) All hybrids are attacked by citrus-canker in varying degrees.

(*a*) The citranges, citrumelos, citradias, citrandarins, citrunshus, and cicitranges, all having *Poncirus trifoliata* as one parent, are extremely susceptible. Apparently all crosses with *P. trifoliata* will yield hardy but susceptible hybrids.

(*b*) The citrangedins, citrangarins, citrangumas, and citrangequats, with susceptible citranges as one parent, are not only hardy, but decidedly resistant to canker; in fact, the citrangequat is practically immune in spite of the fact that it is a rapid grower.

(*c*) The limequats and orangequats are somewhat susceptible.

(*d*) Limelos and orangelos are as susceptible as grapefruit, while clemelos, siamelos, satsumelos, and tangelos are not so resistant as the mandarin oranges.

(*e*) The calarins and calashus are as resistant as either parent, while siamors and bigaraldins are susceptible.

(5) All false hybrids are extremely susceptible.

(6) Leaf texture is apparently an important factor in influencing resistance to *Pseudomonas citri* by its host plants. This phase deserves further investigation.

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PLATE 54

Vines of Green Mountain variety inoculated with juice from mosaic foliage of Irish Cobbler variety. Distinct mottling and ruffling of upper leaves, early dying of lower leaves. Condition of control plants same as vines in Plate 49.

177285°—20——5

PLATE 55

Vines of Bliss Triumph variety inoculated with juice from mosaic foliage of Irish Cobbler variety. Mosaic mottling of upper leaves, early dying of lower leaves. For control see Plate 50.

PLATE 56

Vines of Irish Cobbler variety inoculated with juice from mosaic foliage of the same variety showing bad stage of mosaic. Distinct mottling of young leaves and early dying of foliage. For control see Plate 51.

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PLATE 57

Leaf of *Casimiroa edulis*, with naturally occurring spots from the greenhouse inoculations. Note that the spots are small, unruptured, and occur only along scratches. Natural size.

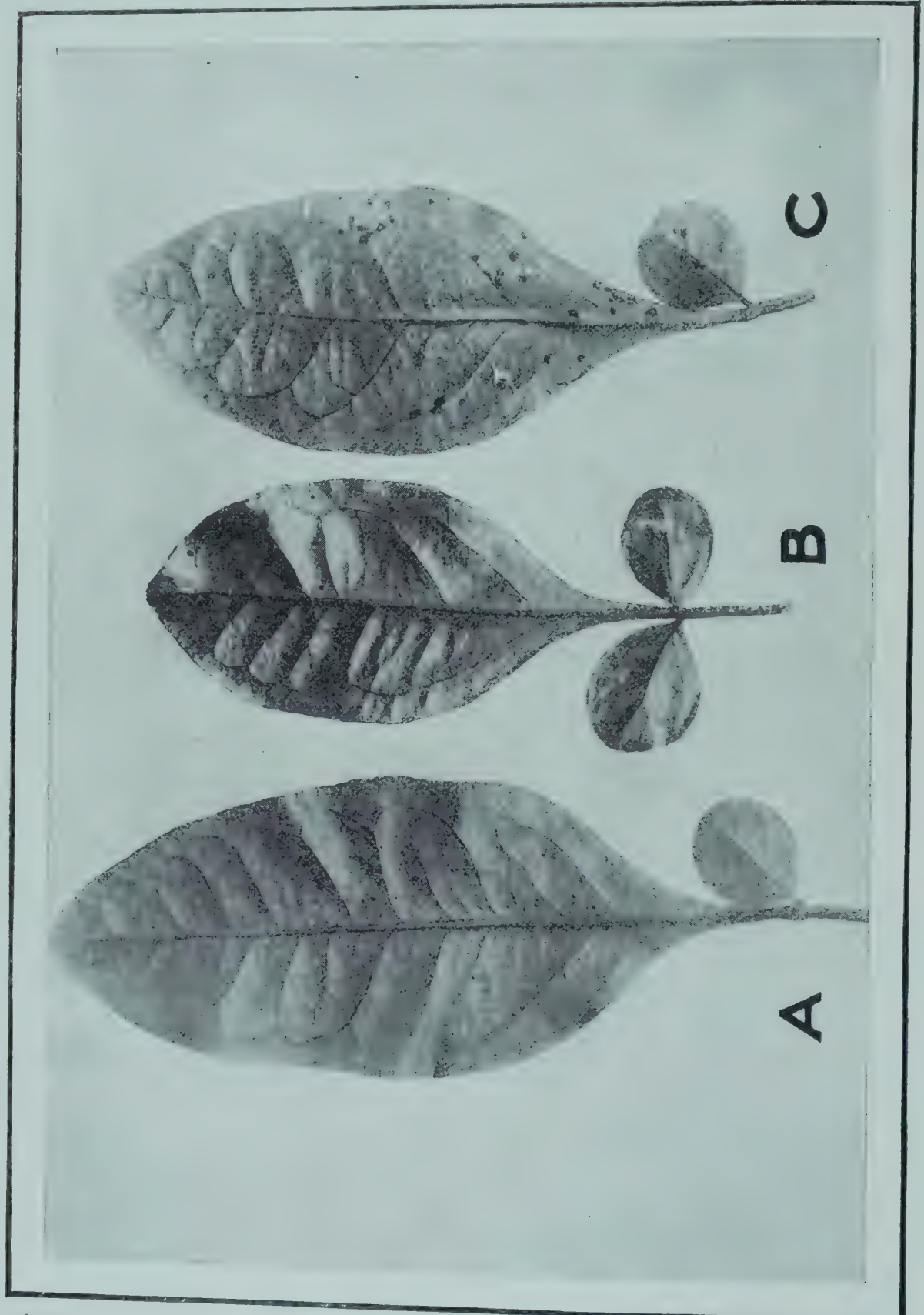

C
B
A

PLATE 58

Infected leaves from plants of *Chaetospernum glutinosum* in the greenhouse experiments, showing the types of canker spots produced:

A.—Spots extremely small and nontypical.

B.—Spots small, oily, raised, and unruptured.

C.—Spots of medium size, ruptured, and slightly corky.

Natural size.

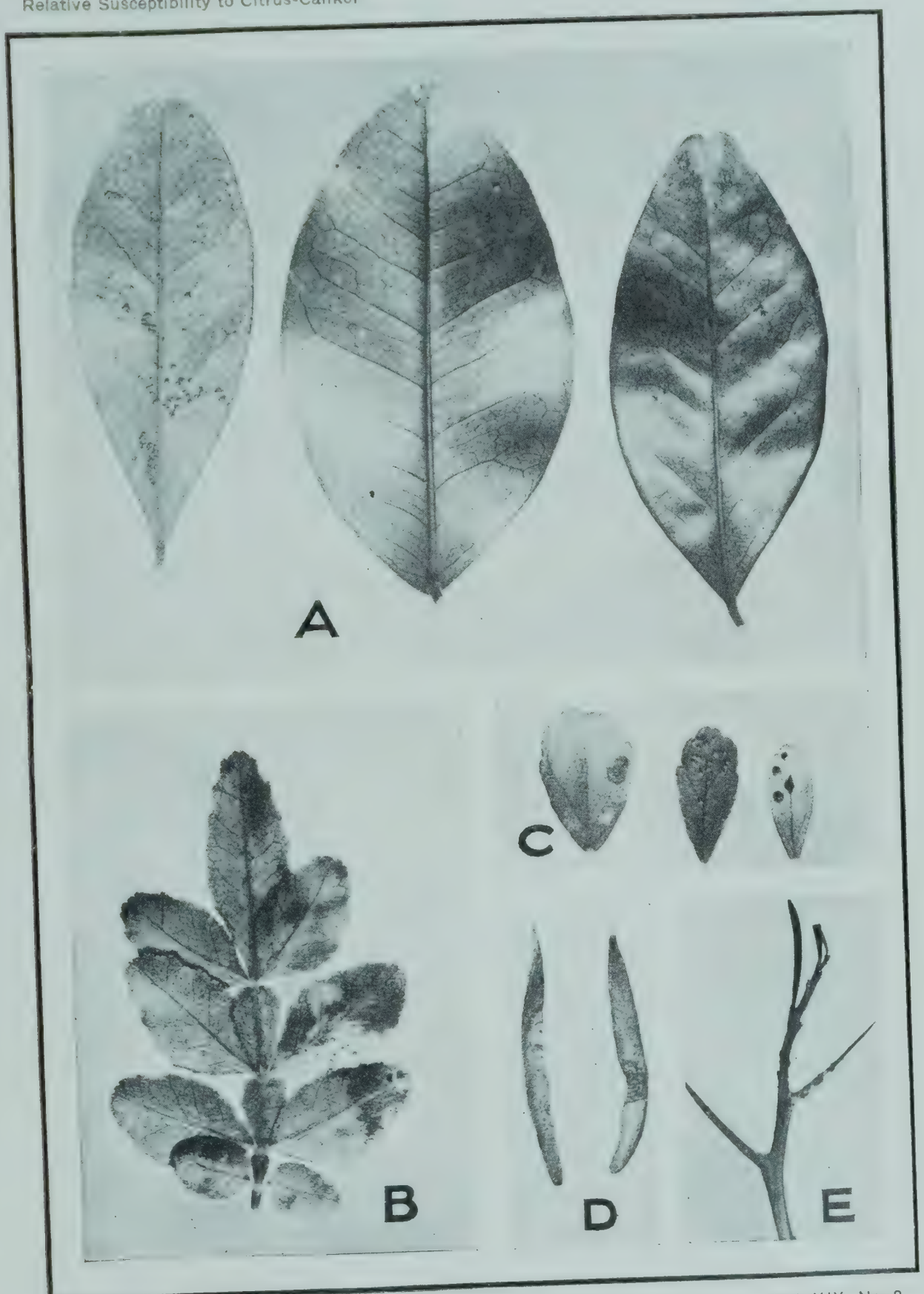
PLATE 59

A.—Leaves of *Atalantia citrioides* and *A. ceylonica* (center) from plants in the greenhouse experiments, showing the canker spots typically produced on these plants. Natural size.

B.—Compound leaf of *Hesperthusa crenulata* from isolation field, with naturally occurring canker spots on two of the leaves. Natural size.

C.—Leaves of *Microcitrus Garrowayi* from plants in the greenhouse experiments, with different types of canker spots. These spots are characteristic of all found on *Microcitrus* spp. × 2.

D, E.—Infected leaves from twigs of *Eremocitrus glauca* from greenhouse plants, showing the large flat spots on the leaves and the rather corky spots on the twig and thorn. × 3.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E

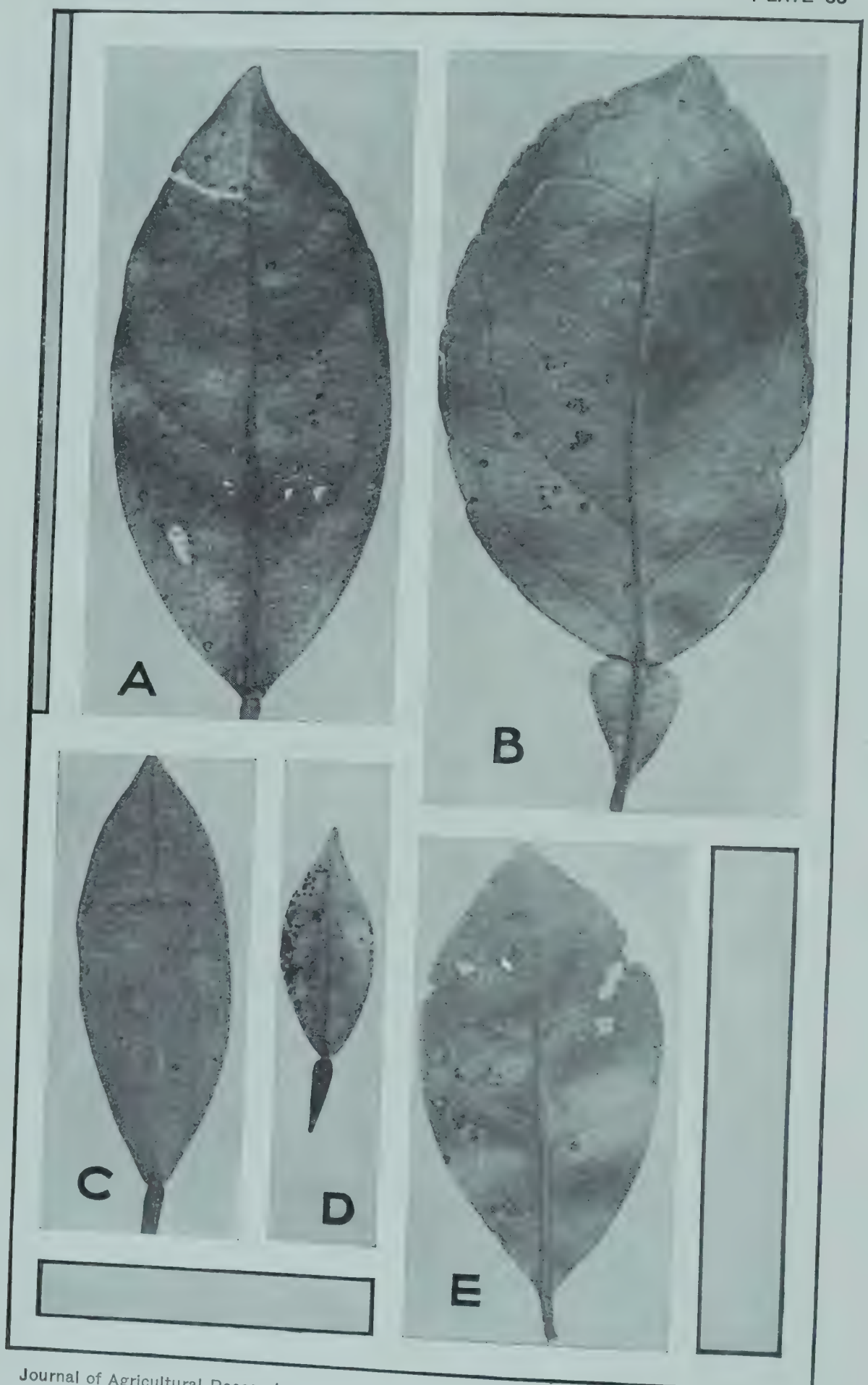
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PLATE 60

A.—Typically infected leaf of *Fortunella margarita*.

B.—Old leaf of *Citrus grandis*, with raised, compact, oily, unruptured spots. Compare leaf texture and type of spots with those of *Fortunella margarita*.

C.—*Fortunella Hindsii*, with ruptured corky spots. Compare with the spots found on *F. margarita*.

D.—*Citrus* sp, Kansu or Yuzu orange. Small spots produced on the leaves of these plants are numerous but never increase in size.

E.—*Citrus aurantifolia*, showing typical infections. All natural size and from greenhouse experiments.

PLATE 61

Upper and lower leaf surfaces of a *Citrus hystrix* leaf with a heavy natural canker infection. The yellow zone around the spots is very distinctly shown. Natural size.

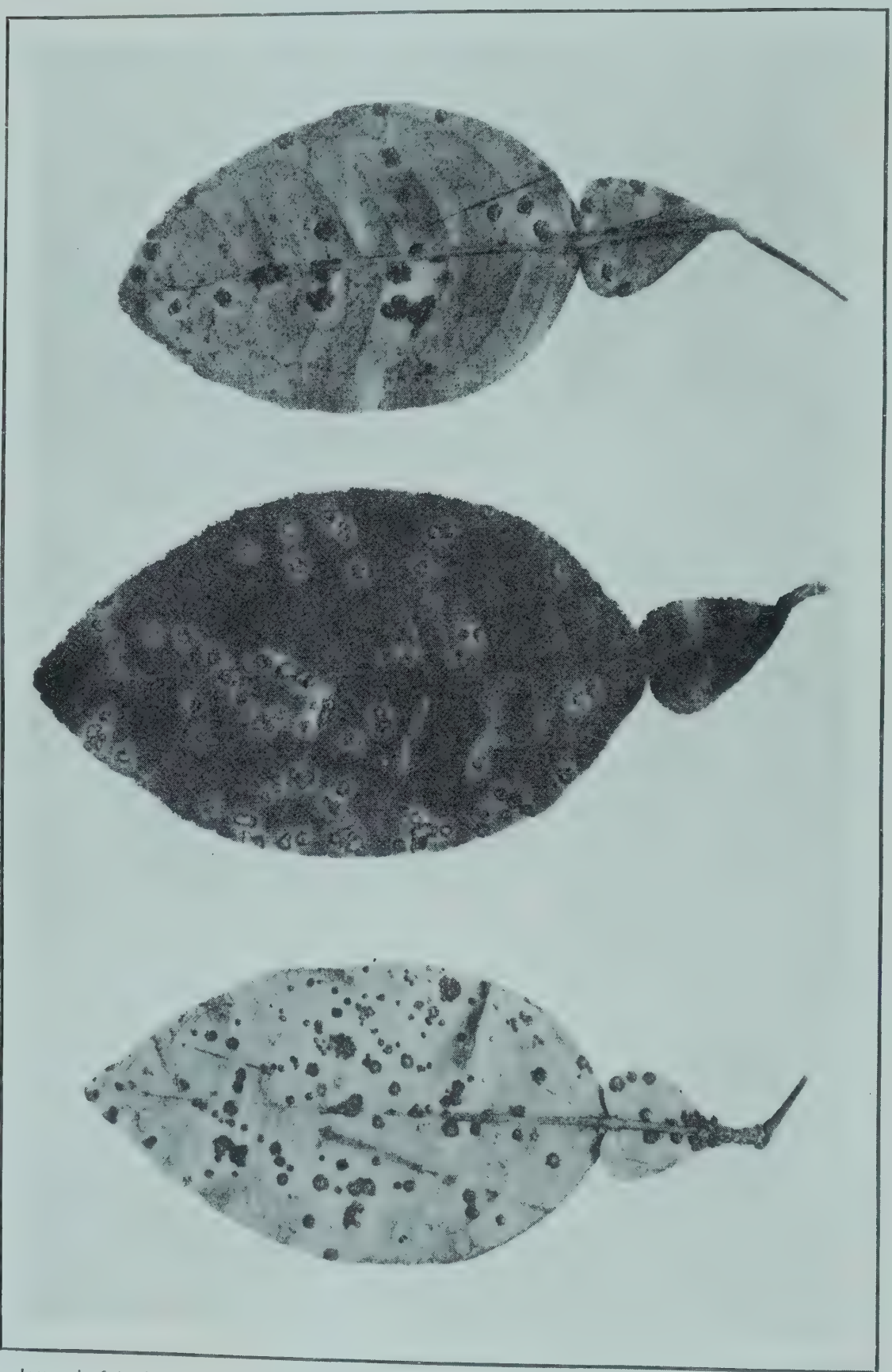

PLATE 62

Typically infected leaves of *Citrus grandis* from field plants showing extreme susceptibility. Note number, size, and corkiness of spots, also the rather large zone surrounding the spots. × ⅔.

PLATE 63

A.—Leaves and twigs of faustrime from greenhouse experiment with typical spots. Compare with those on *Microcitrus australis*.

B.—Types of spots found on *Citrus nobilis* (King of Siam, Naranjita, and tangerine). × ½.

C.—Leaf of the citrangequat from greenhouse experiment. The spots here are extremely small and never increase in size. This is one of the few leaves that have been successfully inoculated.

D.—Citrumelo leaf with typical canker spots. All hybrids of *Poncirus trifoliata* have the same type of spot.

E.—Upper and lower surface of a naturally infected leaf of *Citrus mitis* in the field. Practically all spots occur along the midrib.

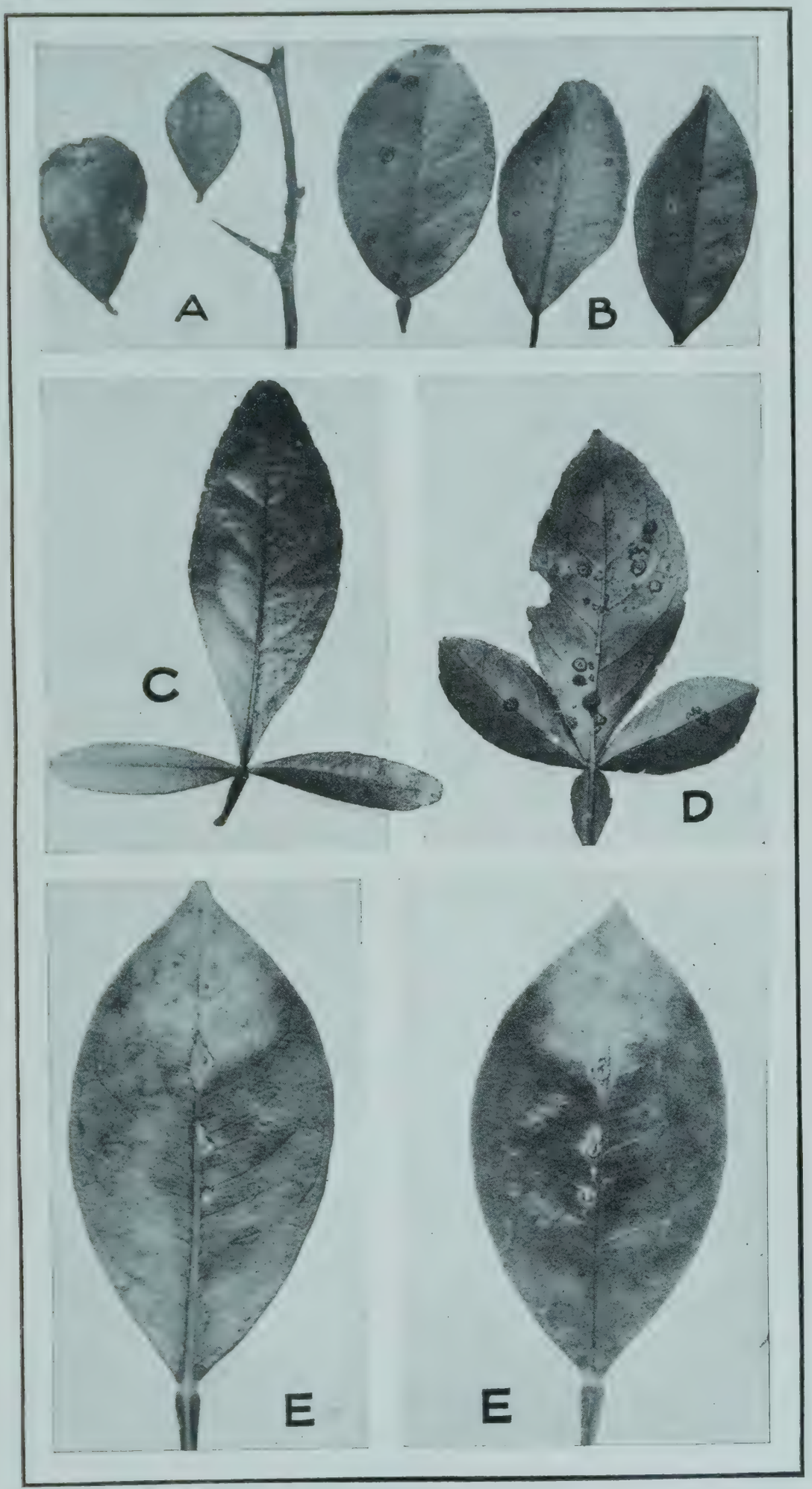
A
B
C
D
E
E

PLATE 64

Naturally infected leaves of *Citrus nobilis* var. *unshiu* from the field, showing various types of spots produced. As a rule the spots on the leaf to the left are found most frequently. All leaves represent rather severe infections. × ¾.

177286°—20——3

PLATE 65

Some of the hybrids of *Porcirus trifoliata*, showing vigor, type of growth, leaf characters, and relative susceptibility to citrus-canker, arranged in order of their susceptibility:

A.—*P. trifoliata.*
B.—Rusk citrange.
C.—Citrumelo.
D.—Citradia.
E.—Citrandarin.
F.—Cicitrange.
G.—Citrangu̇ma.
H.—Citrangequat.

A
B
C
D
E
F
G
H

A
B

PLATE 66

A.—Limelos in the greenhouse inoculation experiments, showing type of growth, leaf characters, and susceptibility to citrus-canker.

B.—Limequats in the greenhouse inoculation experiments, showing type of growth, character of leaves, and susceptibility to citrus-canker. The large, broad leaf forms at the left are more susceptible than the narrower leaf forms at the right.

PLATE 67

A.—Siamelos in the greenhouse inoculation experiments, showing type of growth, leaf characters, and susceptibility to citrus-canker.

B.—Comparison of type of growth, leaf characters, and susceptibility to citrus-canker in clemelo, satsumelo, and tangelo in the greenhouse inoculation experiments.

A
B

A
B

PLATE 68

A.—Results of the greenhouse inoculations with some of the false hybrids. Note defoliation and heavy stem infection.

B.—Tangelos in the greenhouse inoculation experiments, showing type of growth, leaf character, and susceptibility to citrus-canker.

PRESOAK METHOD OF SEED TREATMENT: A MEANS OF PREVENTING SEED INJURY DUE TO CHEMICAL DISINFECTANTS AND OF INCREASING GERMICIDAL EFFICIENCY

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INTRODUCTION

The widespread use of formalin, copper sulphate, and other germicides in seed treatment for the control of seed-transmitted diseases is generally attended by decreased and retarded seed germination. Pathogens on the seed coats, present as dry bacteria, fungus spores, or dormant mycelium, are usually in a resting stage and as such require the use of disinfectants in a fairly strong concentration—1 to 80 for copper sulphate ($CuSO_4$) and 1 to 200 or 1 to 320 for formalin (CH_2O)—which often act very detrimentally on the germinating seed. Even much weaker solutions—1 to 200 for copper sulphate and 1 to 400 for formalin—exhibit retarding and killing effects when used on wheat. The use of lime after copper sulphate, while beneficial to some extent, does not entirely prevent seed injury, nor has the detrimental effect of formalin been so far fully counteracted. The economic importance of the annual loss of grain due to seed treatment is such that during the recent war it occasioned an elaborate series of tests of standard grain disinfectants by the War Emergency Board of the American Phytopathological Society.

In fact (*3*)[2]—

> the difficulty of avoiding injury to the seed from treatment that is too severe or from improper drying after treatment has undoubtedly had more influence in preventing the general spread of the practice of disinfecting seed grain than has the cost of materials or the difficulty of the treatment itself.

In the course of investigations on the blackchaff bacterial disease of wheat (*5*, *6*, *7*, *8*), under the direction of Dr. Erwin F. Smith, a new treatment (*1*) of seed wheat with formalin and copper sulphate has been discovered whereby seed injury due to these disinfectants is either entirely eliminated or is reduced to a negligible minimum, while at the same time the bacteria are rendered more susceptible to the action of the disinfectant. The result has been accomplished by a correlation of two

[1] The author wishes to acknowledge his indebtedness to Dr. Erwin F. Smith for helpful criticism and advice throughout the course of this investigation.

[2] Reference is made by number (italic) to "Literature cited," p. 392.

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fundamental principles of bacteriology and physico-chemistry: First, the established fact that microorganisms in an active vegetative condition or just resuming activity are more susceptible to destructive agents than when in a dry or dormant state; second, the law governing the diffusion of dissolved substances whereby a solvent has a diluting effect on any solute diffusing into it from a stronger solution.

EXPERIMENTAL METHODS

Numerous experiments with the use of dry heat (90° to 110° C. for various periods) for the control of the blackchaff disease had indicated that it was attended either with serious seed injury or else with incomplete control of the bacteria so as to render it unsatisfactory for field use. Exposure to 105° C. for one hour killed all the bacteria, but it also killed a very considerable part of the seeds, while in every case exposure to temperatures between 90° and 100° C. failed to kill all the bacteria. Earlier experiments with mercuric chlorid (1:1,000) and with copper sulphate (1:1,000) begun by Dr. Smith were abandoned because many seeds were killed by the mercuric chlorid and not quite all the bacteria were killed by the copper sulphate. A number of experiments to determine whether the formalin treatment for cereals might also be applicable as a means of controlling the blackchaff disease showed marked injury to the seeds but gave a fairly satisfactory control. The lesser amount of seed injury growing out of long exposures as compared with short exposures is what led to the discovery of the treatment described in the present paper.

Two parallel series of experiments were carried out—one, to determine the effects on the blackchaff organism of various treatments, the other to observe the effects of the same treatments on the germination of wheat. Nine of the most widely grown wheat varieties were used in the latter series: Turkey, Fultz, Marquis, Bluestem, China, Preston, Poole, Fife, and Fulcaster, obtained through the courtesy of the Office of Cereal Investigations.

Treatments for the seed-germination tests were made as follows, except as otherwise stated. Seeds counted out in sets of 100 were placed in loose cheesecloth bags and soaked thoroughly for 10 minutes in the solution to be tested. The surplus liquid was then drained off, and the seeds were placed in covered moist chambers containing several layers of filter paper previously rinsed with the same solution. After definite periods of time the seeds were removed, spread out to dry overnight, and planted the next day in flats or pots in the greenhouse. Untreated seeds were also planted as controls. Later in the course of the work treated seeds were planted outdoors at the Arlington Experimental Farm.

The effect of the various treatments on the blackchaff organism was determined by the following method, devised by Dr. Smith. Wheat seeds in lots of 100 or more were placed in double envelopes of filter paper and sterilized by dry heat at 150° to 160° C. for three hours, in order to kill all internal and surface organisms. After they had cooled, the envelopes were opened with aseptic precautions and the seeds were thoroughly coated with blackchaff bacteria taken from 2- to 4-day-old nutrient agar or potato cultures and used as a heavily clouded bacterial suspension in sterile tubes of tap water. In this way five isolations of the blackchaff organism from as many States were tested. The seeds, after soaking in the bacterial suspension for 20 minutes, were replaced in the envelopes and allowed to dry overnight. By this method each kernel was coated with a dry film of live bacteria such as would occur on badly infected seed under natural conditions. The next day the inoculated and dried seeds were dropped into sterile test tubes containing the disinfectant to be tested. The liquid was drained off after it had acted 10 minutes. The tubes containing the seeds, which now had a thin layer of the solution around each kernel, were placed in moist chambers previously rinsed with the same solution. After definite periods the seeds, still moist, were replaced in the sterile envelopes to dry overnight. The next day they were transferred to nutrient agar previously determined to be suitable for the organism, in poured plates, 10 seeds per plate. Each seed was handled with forceps which had been dipped in alcohol and flamed. Control seeds which had been inoculated but not subsequently treated were also planted on this agar. After at least nine days the final records were made. The controls usually developed a typical blackchaff colony around each kernel. Treated seeds, if all the bacteria thereon were killed by the solution used, remained sterile unless contaminated by other organisms or slowly produced blackchaff colonies if the disinfectant had not been fully effective. This method is a good index of the effect on the bacteria of the various treatments studied. The seeds are sterilized by dry heat externally and internally without leaving any antiseptic residue such as might be left by chemical sterilization. The treatment under consideration is performed upon dried but live bacteria which are found on the seed coat exactly as they would occur in field practice, except that ordinarily they would be less viable and there would be fewer of them. The subsequent exposure on agar plates to optimum conditions for bacterial growth reveals the effect of the treatment, in that the bacteria on the seeds, if uninjured by the treatment, are enabled to develop characteristic colonies, the slowness of their development being a very good index of the proportion killed. Over 5,500 seeds were treated in this manner in the course of the investigation.

EXPERIMENTAL STUDIES

EFFECT OF FORMALIN TREATMENT ON BACTERIUM TRANSLUCENS VAR. UNDULOSUM SMITH, JONES, AND REDDY

As the bacterial blackchaff disease has often been found together with the covered smut of wheat in western fields, experiments were first performed to determine whether the formalin treatment for smut would at the same time control the blackchaff disease. Following the procedure above outlined, sterilized wheat seeds were inoculated with virulent isolations of the blackchaff organism and then treated for various periods with formalin 1 to 200 and 1 to 400 (1 part of 36.6 per cent formalin to 200 or 400 parts sterile tap water) and finally dried and planted on agar plates. The results of treatments of over 3,000 wheat seeds in four experiments are summarized in Table I.

TABLE I.—*Effect of formalin treatment on blackchaff bacteria on wheat seeds*

Treatment.	Total number of seeds used.	Percentage developing typical blackchaff colonies.	Percentage remaining sterile.	Percentage contaminated with fungi or bacteria other than blackchaff.
Formalin 1:200 overnight	294	0.0	82.3	17.7
Formalin 1:400 for 3 hours	1,000	.1	92.6	7.3
Formalin 1:400 for 6 hours	1,000	.0	96.7	3.3
Formalin 1:400 for 12 hours	597	.0	84.7	15.3
Controls inoculated but not treated	320	82.6	16.2	1.2

The data show that the blackchaff bacteria, dried on wheat seeds as under natural conditions, can be held under control by the formalin 1 to 400 treatment, especially when exposed for six hours or longer.

Since all the formalin used in treating the seeds had evaporated during the overnight drying, no residual solution could have been left on the seeds in the plates to prevent bacterial growth. Neither did 24 to 48 hours' drying after inoculation kill the organisms, as was shown by growth in the controls, which acted as an index of the viability of the dried organisms as well as of the suitability for bacterial growth on the part of the particular lot of media used. The conclusion is evident that absence of blackchaff bacterial growth around treated seeds was due only to the effect of the treatment.

GREENHOUSE EXPERIMENTS WITH FORMALIN AND COPPER SULPHATE

EFFECT OF FORMALIN TREATMENT ON GERMINATION OF WHEAT SEED

Parallel with the experiments made to determine the effect on the bacteria, a series was carried out to determine the effect of the two formalin solutions, as used above, on the germination of wheat seed. The 1 to 200 strength formalin was not tried after the second test because

it appeared too injurious to germination to be of any practical value in the field. A total of 6,300 seeds of three varieties was treated in this series and planted in flats in the greenhouse. Records of germination, counting all seedlings above ground on the seventh day after planting for experiment I and those above ground on the ninth day for experiments II and III, are given in Table II.

TABLE II.—*Effect of formalin treatment on germination of wheat seed*

Treatment.	China.				Bluestem.				Turkey.			
	Average percentage of germination.				Average percentage of germination.				Average percentage of germination.			
	Exp. I.	Exp. II.	Exp. III.	Average.	Exp. I.	Exp. II.	Exp. III.	Average.	Exp. I.	Exp. II.	Exp. III.	Average.
Control	78	63	63	68	50	53	43	49	56	63	75	65
Formalin 1:400 for 3 hours	56	48	40	48	24	26	31	27	42	45	65	51
Formalin 1:400 for 6 hours	53	40	45	46	25	34	35	31	48	53	62	54
Formalin 1:400 for 12 hours	74	53	46	58	39	33	40	37	50	54	68	57
Formalin 1:200 for 3 hours	39	15	....	27	9	19	....	14	23	31	....	27
Formalin 1:200 for 6 hours	37	33	....	35	13	17	....	15	17	32	....	25
Formalin 1:200 for 12 hours	57	29	....	43	9	16	....	13	34	36	....	35

The preceding table shows grave injury to germination where the stronger solution was used. There was also marked retardation of germination. Formalin 1 to 400, while much less harmful, caused an appreciable decrease in germination as compared with the controls. It was observed, however, that the 12-hour treatment (1:400) invariably produced less retardation and loss in germination than the 3-hour treatment. This was repeatedly evident for each variety (Pl. 69). A fourth test for Turkey wheat (part of experiment IV), using 400 seeds treated with formalin 1 to 400 for 1 hour, 400 seeds treated 12 hours, and 100 seeds untreated, gave on the sixth day after planting 45 per cent germination for the 1-hour treatment, 59 per cent for the 12-hour treatment, and 62 per cent for the controls. These results, so contrary to what might have been expected, led to the experiments to be described. A search of the literature after these results had been obtained disclosed a similar condition in a number of cases not commented on by the authors—that is, less injury from long exposures than from short ones.

Such a condition is found in an analysis which I have made of the data presented by a subcommittee of the War Emergency Board of Plant Pathologists (*4*) on the effect of formalin 1 to 320 acting for various periods on different cereal seeds. With wheat, in 18 tests out of 25

the short 2-hour treatment shows more injury than a longer treatment; with barley, 14 out of 19 tests show more injury from the short treatment; and so with oats in 29 out of 41 tests and with rye in 2 out of 3 tests. In some cases there is a steady decrease of injury as the treatment period lengthens.

A study of the tables given by Stuart (9) in his paper on the effect of formalin on oat germination shows almost invariably greater injury to germination caused by 2-hour treatment than by 4-hour treatment of seeds, and a similar effect on the final yield of grain and straw—a fact not commented on by that writer.

These facts led to the conjecture that the formaldehyde content in the seeds at the end of 3 hours was really stronger than in the 12-hour treated seeds. Such a condition might be explained by the hypothesis that the dry seeds absorb the formaldehyde itself more rapidly than they do the water and that by diffusion later this is diluted to a strength more like the original solution through continued absorption of water by the cell walls and cells.

Theoretically, therefore, if the 3-hour treatment could be made in such a way that the final solution content of the seeds would be comparable in amount and dilution with that finally present in 12-hour treated seeds, the effects on germination should also be similar. By impregnating the cell walls and cells of dry seeds with water and then treating with formalin for three hours, it appeared as if this result might be attained; for, in accordance with the laws of diffusion of dissolved substances, the formalin should be diluted as it diffused into the water-saturated seed tissues.

Acting on this hypothesis, wheat seeds were first soaked in tap water for 10 minutes, drained, and kept moist for 9 hours, then soaked thoroughly in formalin 1 to 400 for 10 minutes, drained, and kept moist for 3 hours in order that the water absorbed during the first 9 hours might weaken the full strength solution diffusing into the cells during the next 3 hours and might result in less injury than was caused by the 3-hour treatment of dry seeds. Following this, numerous experiments were made, varying the length of time during which the seeds were kept moist but starting out always with a preliminary short plunge into water. This method—short exposure under water followed by varying lengths of exposure to moist air (covered)—has been designated throughout this paper as the "presoak" method of seed treatment. In the same way, whenever exposure to formalin is mentioned it means always that the seeds were plunged into the formalin water solution for a short period only (usually 10 minutes) and then kept moist (covered) for the designated number of hours.

The seeds of two varieties so treated were planted in the greenhouse with 12-hour treated seeds and controls. Table III records the results observed.

TABLE III.—*Effect of 9 hours' presoaking followed by formalin 1 : 400 treatment*

Treatment.	Percentage of germination.					
	China.	Blue-stem.	China.			Marquis, Exp. VI.
			Exp. V.	Exp. VI.	Average.	
Control	70	78	46	50	48	59
Formalin 1:400 for 10 minutes, covered 12 hours	60	60	40	43	42	56
Formalin 1:400 for 10 minutes, covered 3 hours	.....	.....	35	23	29	49
Water for 10 minutes, covered 9 hours, formalin 1:400 for 10 minutes, covered 3 hours	67	72	45	42	44	58

Table III shows for the presoaked seeds not only a decrease in injury over the 3-hour treated seeds as previously observed but also a decided increase in germination over the seeds treated 12 hours with formalin. The latter show a loss of 10 to 18 per cent, the former a loss of only 3 to 6 per cent. At the same time the presoaked seeds produced larger and more vigorous plants than the controls.

Very clearly the presoak treatment followed by 3 hours of formalin treatment showed a distinct advantage over the usual formalin treatment. As this appeared to be a promising method of reducing formalin injury, a thorough test was then made with all the varieties of wheat at hand. It appeared possible that for some varieties a 9-hour presoak might begin germination before treatment, thus rendering the seeds very susceptible to injury, whereas, a formalin-treatment period longer than 3 hours appeared desirable for control purposes. For these reasons, the presoak period was reduced to 6 hours, followed by a 6-hour treatment with formalin.

EFFECT OF 6 HOURS' PRESOAKING FOLLOWED BY FORMALIN 1 TO 400 TREATMENT ON GERMINATION OF WHEAT SEED

The presoak treatment in every instance was given by soaking the seeds 10 minutes in water, then draining off the surplus water and keeping the seeds in moist chambers 6 hours, allowing the seeds to absorb the surface moisture film during this period. After shaking off all possible surface water, the next step was to soak the seeds thoroughly in a 1 to 400 formalin solution, stirring and rinsing up and down to bring the solution in contact with each kernel. After 10 minutes in this solution the seeds were removed, drained, and kept moist for 6 hours in moist chambers previously rinsed with the same solution. After treatment the seeds were dried overnight and planted in the greenhouse, 100 seeds per pot, in duplicate or triplicate.

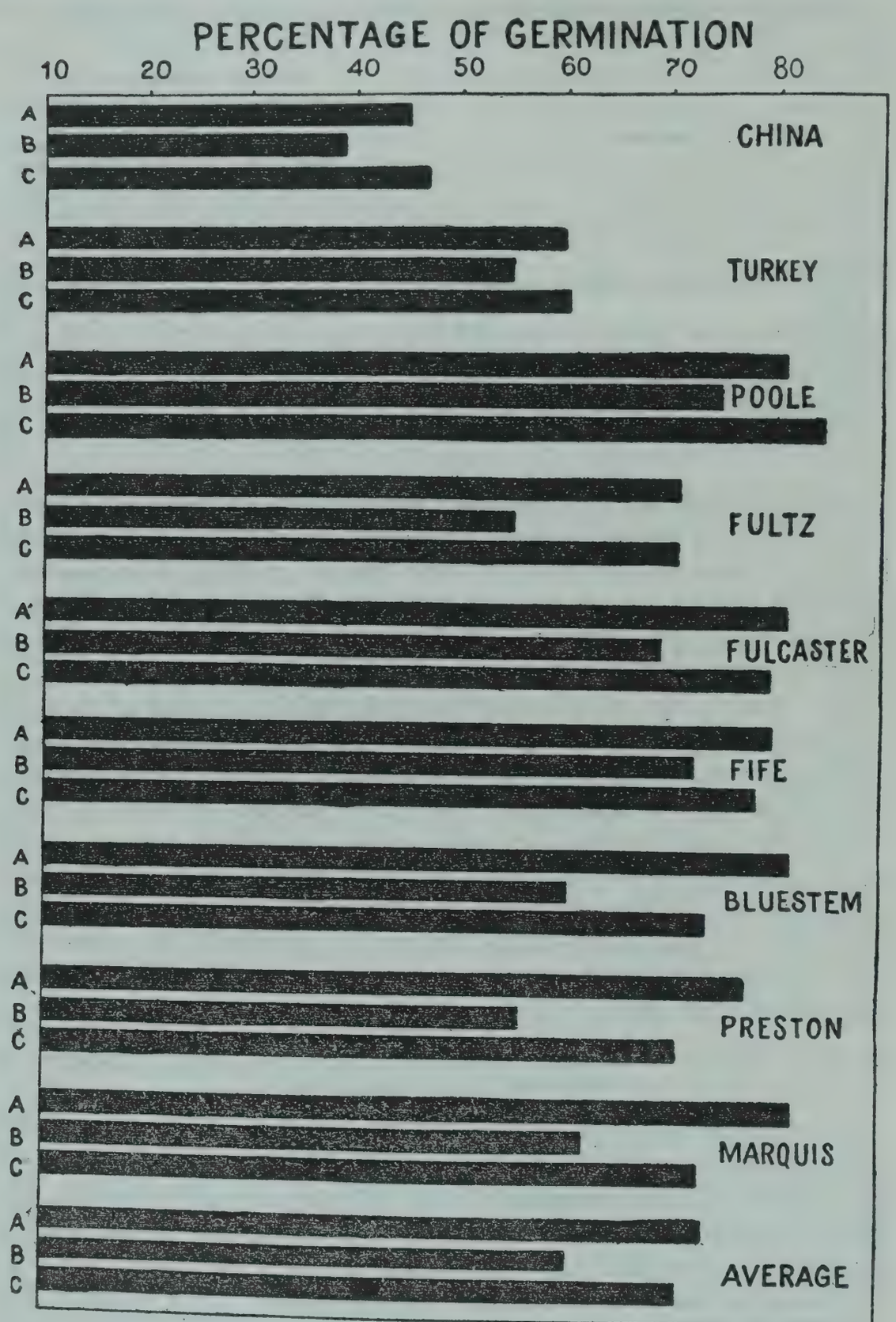

FIG. 1.—Graph showing effect of formalin 1 to 400 treatments with and without presoaking: A, control, untreated; B, seeds soaked in formalin 1 to 400 for 10 minutes, drained, and kept moist (covered) 12 hours, dried overnight, and planted; C, seeds soaked in water 10 minutes, drained, and kept moist (covered) 6 hours, soaked in formalin 1 to 400 for 10 minutes, drained, and kept moist (covered) 6 hours, dried overnight, and planted. Records of germination were taken on the sixth day after planting in the greenhouse.

Using a 6-hour presoak followed immediately by a 6-hour treatment with formalin 1 to 400, 6 experiments were carried on in the greenhouse with 23,700 seeds of nine varieties, the test for each variety being repeated several times. Table IV and figure 1 show the data obtained on the sixth day after planting in each test, this date being chosen as showing not only the relative percentage of germination but particularly revealing any retardation or acceleration. At the same time, the effect of this method on the blackchaff bacteria was determined, as discussed later.

TABLE IV.—*Effect of 6 hours' presoaking followed by formalin 1 : 400 treatment on germination of wheat seed*

Treatment.	Average percentage of germination.											
	Pilot.				Bluestem.				Preston.			
	Exp. V.	Exp. VI.	Exp. VII.	Average.	Exp. V.	Exp. VI.	Exp. VII.	Average.	Exp. V.	Exp. VI.	Exp. VII.	Average.
Control	89	74	75	79	83	79	82	81	79	75	77	77
Formalin 1:400 for 10 minutes, covered 12 hours	75	66	75	72	61	54	66	60	53	51	63	56
Water for 10 minutes, covered 6 hours, formalin 1:400 for 10 minutes, covered 6 hours	77	71	86	78	74	64	82	73	66	64	82	71

Treatment.	Average percentage of germination.									
	Marquis.				China.			Turkey.		
	Exp. V.	Exp. VI.	Exp. VII.	Average.	Exp. V.	Exp. VI.	Average.	Exp. V.	Exp. VI.	Average.
Control	82	79	84	82	52	38	45	60	61	61
Formalin 1:400 for 10 minutes, covered 12 hours	54	62	70	62	44	34	39	60	52	56
Water for 10 minutes, covered 6 hours, formalin 1:400 for 10 minutes, covered 6 hours	61	75	82	73	50	44	47	71	50	61

Treatment.	Average percentage of germination.							
	Poole.				Pultz.			
	Exp. VIII.	Exp. IX.	Exp. X.	Average.	Exp. VIII.	Exp. IX.	Exp. X.	Average.
Control	72	80	92	81	55	83	74	71
Formalin 1:400 for 10 minutes, covered 6 hours	67	85	70	74	57	70	57	61
Formalin 1:400 for 10 minutes, covered 12 hours	65	82	79	75	42	66	62	57
Water for 10 minutes, covered 6 hours, formalin 1:400 for 10 minutes, covered 6 hours	76	89	89	88	60	78	76	71

TABLE IV.—*Effect of 6 hours' presoaking followed by formalin 1 : 400 treatment on germination of wheat seed*—Continued

Treatment.	Fulcaster.				Turkey.			
	Exp. VIII.	Exp. IX.	Exp. X.	Average.	Exp. VIII.	Exp. IX.	Exp. X.	Average.
Control	82	84	79	82	41	74	64	59
Formalin 1 : 400 for 10 minutes, covered 6 hours	62	67	60	63	[a]56	64	48	56
Formalin 1 : 400 for 10 minutes, covered 12 hours	68	72	69	70	35	67	61	54
Water for 10 minutes, covered 6 hours, formalin 1 : 400 for 10 minutes, covered 6 hours	77	80	83	80	46	71	65	57

[a] Result from one pot only, the other having been overturned.

For each variety of wheat used the result is the same—a marked decrease in retardation and injury to germination where the presoak method

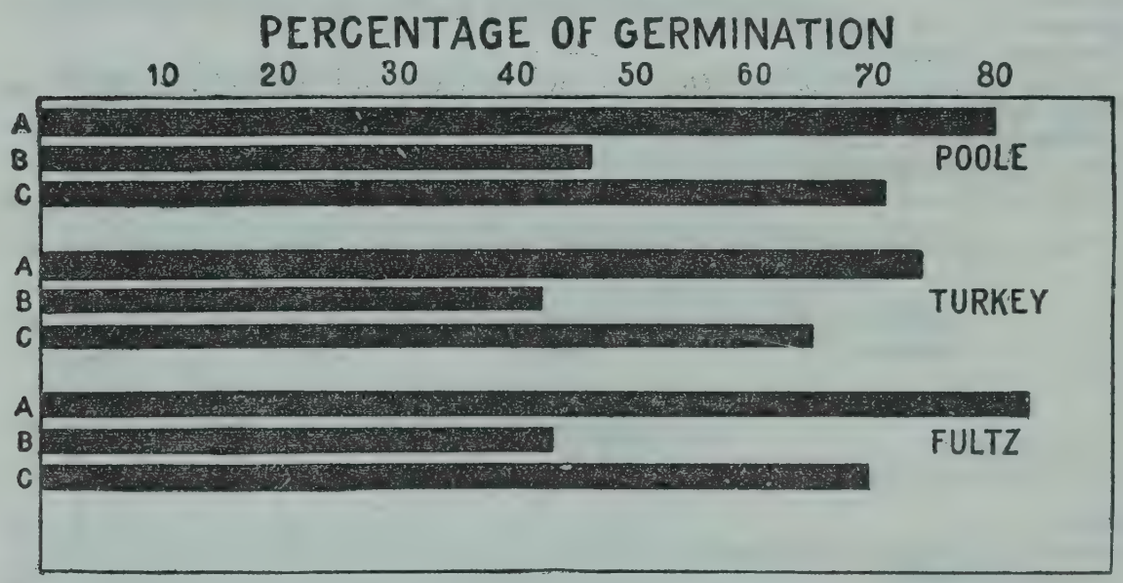

FIG. 2.—Graph showing effect of formalin 1 to 200 treatments with and without presoaking: A, control, untreated; B, seeds soaked in formalin 1 to 200 for 10 minutes, drained, and kept moist (covered) 6 hours, dried overnight, and planted; C, seeds soaked in water 10 minutes, drained, and kept moist (covered) 6 hours, then soaked in formalin 1 to 200 for 10 minutes, drained, and kept moist (covered) 6 hours, dried overnight, and planted. Records of germination were taken on the sixth day after planting in the greenhouse.

of treatment was used, as compared with the 6- or 12-hour formalin treatment without presoaking. In the case of the three varieties most susceptible to formalin—Bluestem, Preston, and Marquis—germination of the presoak-treated seeds is within 6 to 9 per cent of the controls, while there is a reduction of 20 to 21 per cent in the seeds treated without presoaking. The other six varieties show practically all injury eliminated by the presoak treatment. The relative appearance of controls, treated plants, and presoak-treated plants on the sixth day is shown in Plates 70 and 71. A very noticeable stimulation in vigor was observed in

all of the presoak-treated seeds as compared with the controls. This is brought out also in Plate 72.

EFFECT OF 6 HOURS' PRESOAKING FOLLOWED BY FORMAILN 1 TO 200 TREATMENT ON GERMINATION OF WHEAT SEED

The beneficial effect of the presoak method is strikingly shown in an experiment where a much stronger solution of formalin was used. Seeds of three varieties were treated for 10 minutes with formalin 1 to 200 and were then kept moist (covered) for 6 hours, dried overnight, and planted in the greenhouse. Another set of seeds received the same treatment but were first soaked in water 10 minutes, drained, and kept moist 6 hours before receiving the formalin treatment. This strength of 1 to 200 had previously been found to cause a very considerable injury to germination. Table V and figure 2 show the percentage of germination on the sixth day.

TABLE V.—*Effect of 6 hours' presoaking followed by formalin 1 : 200 treatment on germination of wheat seed*

Treatment.	Average percentage of germination.		
	Poole.	Turkey.	Fultz.
Control	80	74	83
Formalin 1 : 200 for 6 hours	46	42	43
Water for 6 hours, formalin 1 : 200 for 6 hours	71	65	70

Here the 6-hour formalin 1 to 200 treatment reduced germination 32 to 40 per cent below that of the controls, while the reduction was only 9 to 13 per cent where the same treatment was preceded by 6 hours' water presoak (Pl. 73.)

EFFECT OF 6 HOURS' PRESOAKING FOLLOWED BY FORMALIN 1 TO 320 TREATMENT ON GERMINATION OF WHEAT SEED

Formalin 1 to 320, or one pound of formalin to 40 gallons of water, was next used, since that is the strength now recommended for the cereal smuts. Besides the presoak procedure so far followed, a test was made (experiment XI) of the effect of an actual soaking in water for 5 hours, followed by thorough draining for a few minutes, then 10 minutes' soaking in the formalin 1 to 320, then covering for 7 hours before drying and planting. Experiment XII was conducted to test the effect of an actual soaking in water for 4 hours, followed by thorough draining for a few minutes, then soaking in formalin 1 to 320 for 10 minutes, draining, covering 6 hours, drying, and planting. The results obtained are shown in Table VI and figure 3.

TABLE VI.—*Effect of 6 hours' presoaking followed by formalin 1 : 320 treatment on germination of wheat seed under greenhouse conditions*

Treatment.	Average percentage of germination.					
	Poole.			Fife.		
	Exp. XI.	Exp. XII.	Average.	Exp. XI.	Exp. XII.	Average.
Control	94	85	90	79	83	81
Formalin 1 : 320 for 10 minutes, drained, covered 6 hours	66	55	61	59	62	61
Formalin 1 : 320 for 10 minutes, drained, covered 12 hours	67	71	69	58	64	61
Water for 10 minutes, covered 6 hours, formalin 1 : 320 for 10 minutes, drained, covered 6 hours	90	88	89	80	90	85
Actual soaking in water 5 hours, formalin 1 : 320 for 10 minutes, covered 7 hours	88	.....	88	77	.....	77
Actual soaking in water 4 hours, formalin 1 : 320 for 10 minutes, covered 6 hours	.....	79	79	.....	85	85

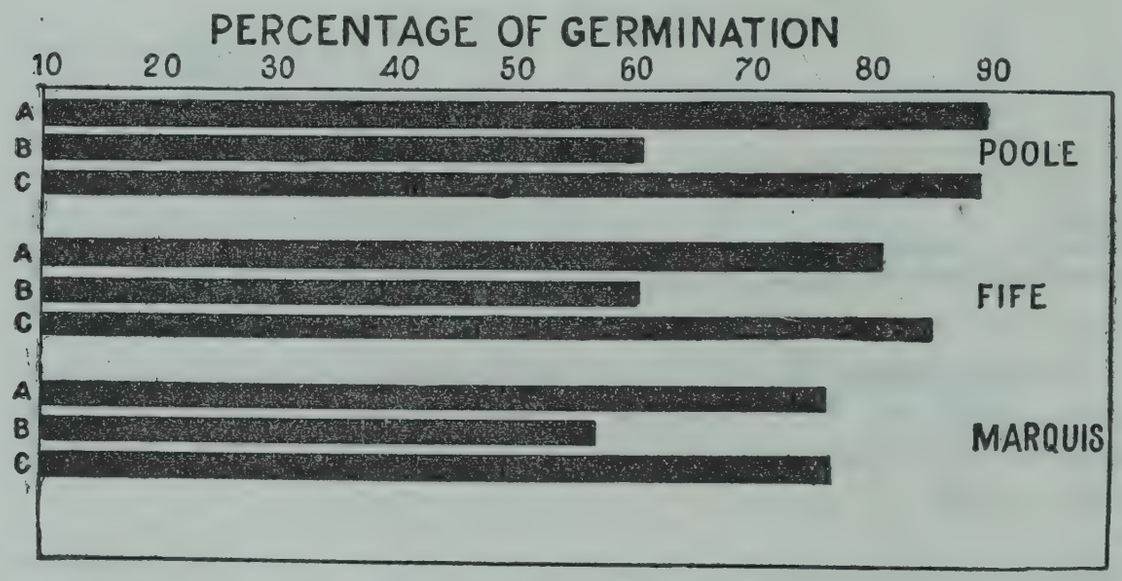

FIG. 3.—Graph showing effect of formalin 1 to 320 with and without presoaking: A, control, untreated; B, seeds soaked in formalin 1 to 320 for 10 minutes, drained, kept moist (covered) 6 hours, dried overnight, and planted; C, seeds soaked in water 10 minutes, drained, kept moist (covered) 6 hours, soaked in formalin 1 to 320 for 10 minutes, drained, kept moist (covered) 6 hours, dried overnight, and planted. Records of germination were taken on the sixth day after planting in the greenhouse.

A marked retardation and diminished germination is shown by both formalin treatments without presoaking. The 6-hour formalin treatment preceded by 6 hours' presoaking yielded plants similar to the controls in percentage of germination, and they were very evidently stimulated, as shown in Plates 74, 75, and 76. Actual soaking in water did not appear to be so beneficial to the vigor of the seedlings as the procedure of merely keeping the seeds moist for 6 hours before treating with formalin. (See Pl. 75, fig. 3.)

EFFECT OF PRESOAKING WHEN USED WITH COPPER SULPHATE FOR WHEAT AND BARLEY SEED

The striking reduction in formalin injury to seed germination when the presoak method was used led to trials of this method in conjunction with copper sulphate. Six hundred wheat seeds of Fife and Fulcaster varieties were soaked in a very strong copper-sulphate solution (1:80, or 1 pound to 10 gallons of water) for 10 minutes, drained 20 minutes, dipped for a moment in milk of lime, and dried. A like number of seeds received the same treatment except that they were kept moist for 8 hours after

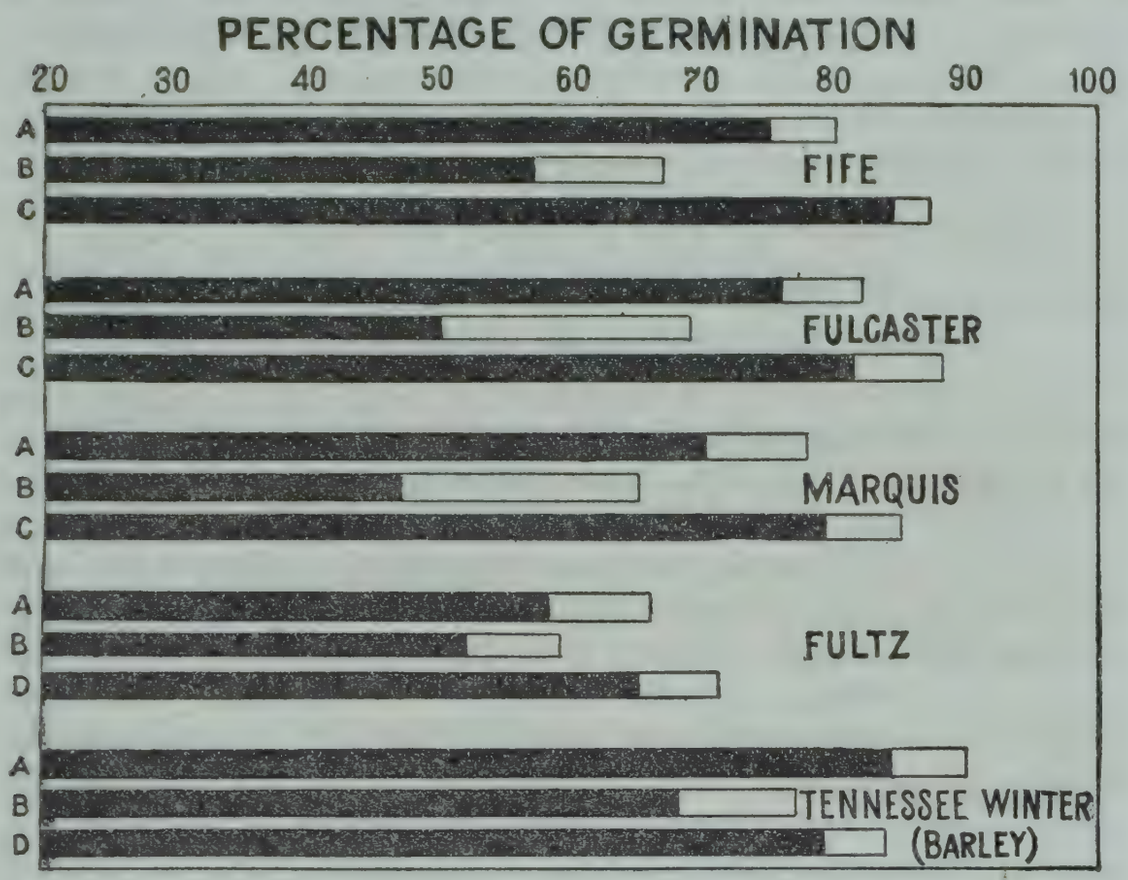

FIG. 4.—Graph showing effect of copper sulphate 1 to 80, with and without presoaking, on wheat and barley seed germination: A, control, untreated; B, seeds soaked in copper sulphate 1 to 80 for 10 minutes, drained, kept moist 20 minutes, then limed, dried overnight, and planted; C, seeds first soaked in water 10 minutes, drained, and kept moist (covered) for 8 hours, then treated as in B; D, seeds first soaked in water 10 minutes, drained, kept moist (covered) for 6 hours, then limed, dried overnight and planted. Records of germination were taken on the fifth and seventh days after planting in the greenhouse.

soaking 10 minutes in tap water. Four hundred seeds were used as controls. All seeds were planted in the greenhouse after drying overnight. The experiment was later repeated, using barley also and wheat seeds of Fultz and Marquis varieties, kept moist in the manner described for 6 hours before treatment. The photographs (Pl. 76, 77) and figure 4 show the results obtained.

In these experiments the injury produced by the copper-sulphate treatment was prevented by the use of the 6- or 8-hour presoak. The 6-hour presoak appears preferable, because a longer period, by starting

seed germination, may render the seed unusually susceptible to the subsequent copper-sulphate treatment and thus defeat its purpose.

A marked increase in the percentage of germination was observed in the presoak-treated seeds over the controls. This was probably due not only to the lack of injury in the former but to the residual effect of the copper sulphate and lime, which, by preventing seed infection through soil organisms, enabled more seeds to germinate. There was also a marked stimulating effect on the growth of the seedlings.

The use of the presoak method of treatment also reduces copper-sulphate injury in barley, as shown in Plate 76, figure 3. The fact that the presoak method can reduce seed injury from formalin and copper sulphate, two disinfectants of widely different chemical nature, suggests the possibility of its use in conjunction with mercuric chlorid also, another commonly used seed disinfectant.

FIELD EXPERIMENTS WITH FORMALIN AND COPPER SULPHATE

EFFECT OF 6 HOURS' PRESOAKING FOLLOWED BY FORMALIN 1 TO 320 TREATMENT ON GERMINATION OF WHEAT SEED UNDER FIELD CONDITIONS

That formalin injury to germination can be greatly decreased under field conditions when the presoak method is used is shown by the following experiment. Using seven wheat varieties, 16,800 seeds were planted on a uniform level plot at the Arlington Experimental Farm. For each variety 12 rows of 200 seeds each were distributed as follows: four rows of controls, four rows of seeds treated with formalin 1 to 320 for 6 hours, and four rows of seeds similarly treated but presoaked 6 hours. The results were striking. In each variety the central four rows, which received the usual treatment recommended for smut, showed a marked decrease in germination (27 to 53 per cent, averaging 38 per cent for the seven plots) while in each case the four rows receiving the presoak formalin treatment scarcely differed in appearance from the controls (Pl. 78). Table VII and figure 5 give the data obtained.

TABLE VII.—*Effect of 6 hours' presoaking followed by formalin 1:320 treatment on germination of wheat seed under field conditions*

Treatment.	Average percentage of germination.													
	Fulcaster		Fife.		Turkey.		Poole.		China.		Bluestem.		Marquis.	
	10th day.	20th day.	10th day.	20th day.	10th day.	20th day.	10th day.	20th day.	10th day.	20th day.	10th day.	20th day.	10th day.	20th day.
Control	60.0	66.3	58.4	59.6	40.6	50.4	60.2	64.3	26.1	32.6	62.2	63.0	50.2	53.9
Formalin 1:320 for 10 minutes, covered 6 hours	32.1	36.8	31.0	41.8	24.2	28.6	20.4	29.8	14.5	21.1	32.5	44.5	24.2	39.1
Presoaked in water, 10 minutes, kept moist 6 hours, formalin 1:320 for 10 minutes, covered 6 hours	52.5	56.4	56.2	58.3	40.8	51.2	53.5	58.3	30.8	35.4	43.6	53.6	46.8	51.6

The results obtained in the field fully corroborate the greenhouse experiments as to the beneficial effect of the presoak method and show that in actual field practice wheat seed injury caused by the formalin treatment recommended for covered smut can be practically eliminated by allowing the seeds to absorb water in the manner prescribed for six hours

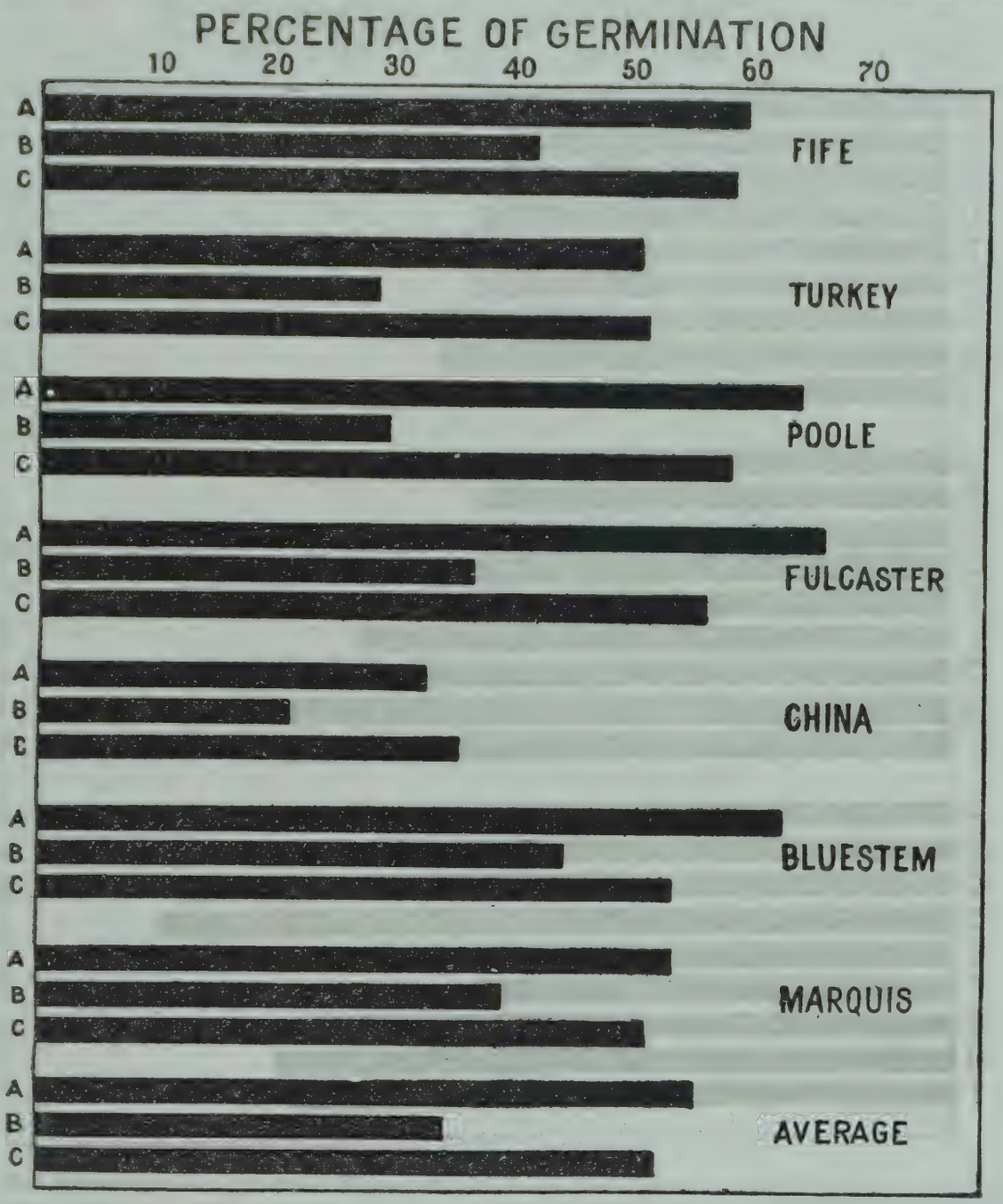

FIG. 5.—Graph showing effect of formalin 1 to 320, with and without presoaking, on wheat seed germination under field conditions: A, control, untreated; B, seeds soaked in formalin 1 to 320 for 10 minutes, drained, kept moist (covered) 6 hours, dried overnight, and planted; C, seeds soaked in water 10 minutes, drained, kept moist (covered) 6 hours, soaked in formalin 1 to 320 for 10 minutes, drained, kept moist (covered) 6 hours, dried overnight, and planted.

before receiving this treatment. The effect of the presoak method of treatment in also eliminating retardation of germination is an important factor in preventing the attack of soil fungi on seeds or very young seedlings unduly delayed in germination. Plate 78 shows the appearance of the field plots on the sixteenth day after planting.

EFFECT OF SIX HOURS' PRESOAKING FOLLOWED BY FORMALIN AND COPPER-SULPHATE TREATMENTS ON HALF-BUSHEL LOTS OF WHEAT SEED

The next series of experiments was made to determine (1) the effect of the presoak method of treatment, using wheat seed in half-bushel lots

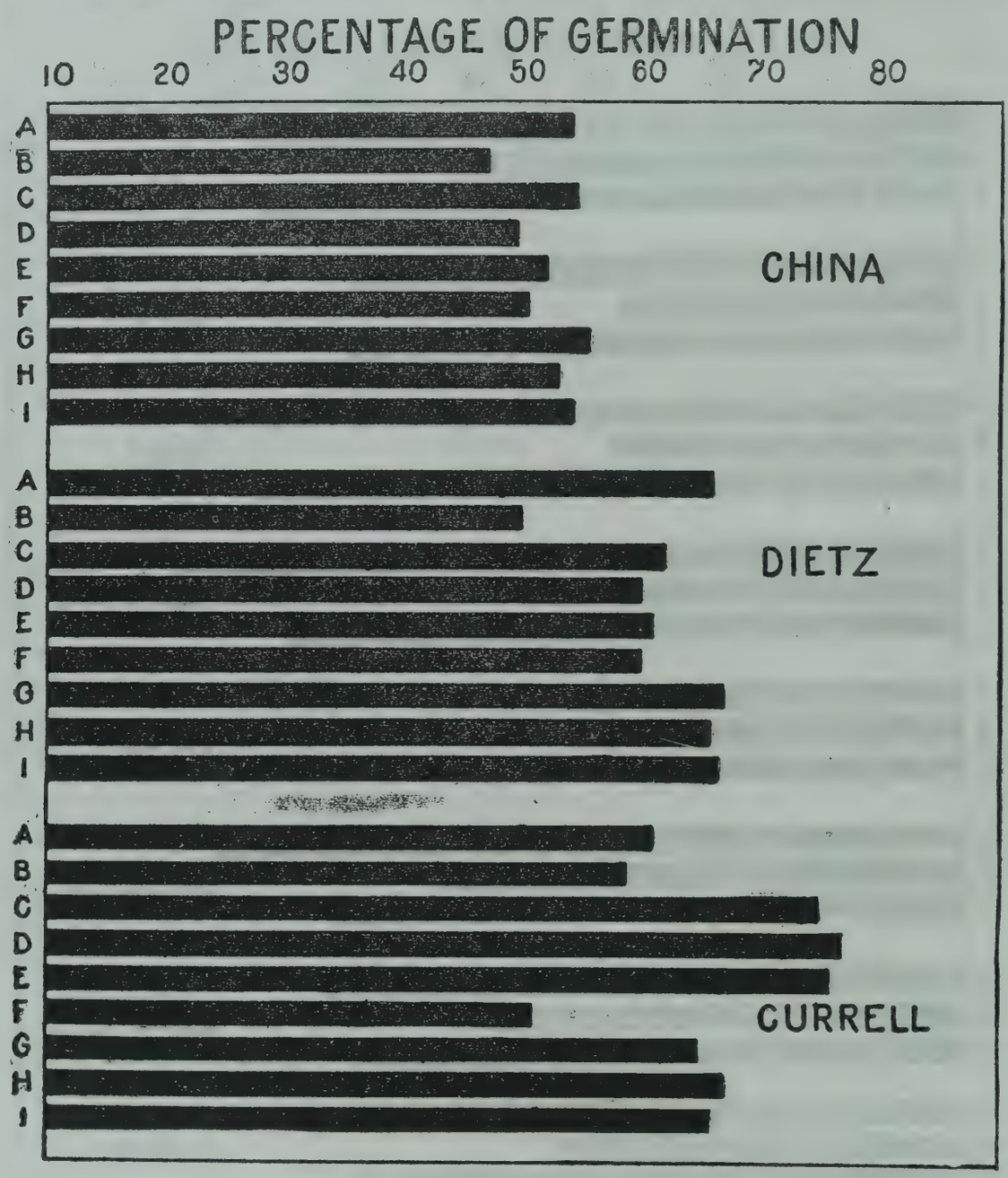

FIG. 6.—Graph showing effect of formalin and copper-sulphate presoak treatments of ½-bushel wheat seed lots: A, control, untreated; B, seeds soaked in formalin 1 to 320 for 10 minutes, drained, covered 6 hours, dried, and planted; C, seeds soaked in water 10 minutes, drained, covered 6 hours, then treated with formalin as in B, and seeds from upper one-fourth planted; D, seeds from central part of same lot as C; E, average germination of C and D; F, seeds soaked in copper sulphate 1 to 80 for ½ hour, followed by milk of lime, and dried; G, seeds soaked in water 10 minutes, drained, covered 6 hours, then treated with copper sulphate as in F, and seeds from upper one-fourth planted; H, seeds from central part of same lot as G; I, average germination of G and H. In the Currell variety the same procedure was used except that the seeds were sprinkled instead of soaked.

as in practical usage; (2) the relative effects of soaking and sprinkling; (3) the result of a possible lack of aeration and accumulation of carbon dioxid in the center of the presoak-treated mass of seeds.

A half bushel each of Dietz and China wheats in bushel bags were soaked in water 10 minutes, drained, and covered 6 hours, then soaked in formalin 1 to 320 for 10 minutes, drained, and covered 6 hours. A similar treatment was made on like quantities of seed, using copper sulphate 1 to 80 for ½ hour after the 6 hours' presoaking, followed by milk of lime. The upper and central parts of each half bushel were dried, and each of the eight lots thus obtained was planted in 10 rows of 300 seeds each. Suitable controls and seeds treated without presoaking were also planted.

At the same time, a bushel of Currell wheat, piled up on canvas, was sprinkled with water and covered for 6 hours. Half of this was then sprinkled with formalin 1 to 320 and covered for 6 hours. The other half was sprinkled with copper sulphate 1 to 80, covered ½ hour, and limed. Seeds from top and center were dried and planted, along with controls and seeds sprinkled without presoaking. The results obtained a month after planting are recorded in figure 6.

The presoak-treated seeds again showed a marked improvement in germination over seeds treated without presoaking. Seeds from the center of the bag are apparently affected to some extent, probably through lack of aeration and the accumulation of carbon dioxid; but the average germination of the presoak-treated seeds is better than that of the seeds treated without presoaking.

The sprinkling method at first sight appears to possess a distinct advantage over the soaking method. In the former, compared to controls, there is a marked increase in germination of seeds sprinkled first with water and after six hours with the disinfectant. This is most probably due to the incompleteness of the sprinkling method, since the disinfectant can not reach each kernel as in the soaking method. Hence a large number of seeds, affected only by the water vapor of the preliminary sprinkling, receive the stimulation due merely to the absorption of water and drying before planting.

EFFECT OF PRESOAK METHOD ON BACTERIUM TRANSLUCENS VAR. UNDULOSUM

EFFECT OF SIX HOURS' PRESOAKING FOLLOWED BY FORMALIN 1 TO 400 TREATMENT ON BLACKCHAFF BACTERIA ON SEEDS PLANTED ON NUTRIENT AGAR

A series of experiments was carried out parallel with the germination experiments, using 2,360 seeds, to determine whether the 6-hour formalin treatment when preceded by a 6-hour presoak would destroy or prevent the growth of the blackchaff bacteria. Heat-sterilized wheat seeds were heavily inoculated, using four virulent isolations of the blackchaff organism, and dried overnight as before described. The next day the seeds were placed in tubes of sterile tap water, which was drained off after 10 minutes. The tubes containing the seeds were placed in moist

chambers for 6 hours to maintain a thin film of moisture around each kernel throughout this period. The subsequent treament with a formalin solution, 1 to 400, in sterile tap water was made in the same manner—that is, by pouring the formalin solution on the seeds, draining if off after 10 minutes and placing the tubes in moist chambers rinsed with a formalin 1 to 400 solution. After 6 hours' treatment the seeds were replaced in sterile envelopes, dried overnight, and planted on agar plates. Control seeds, inoculated but not treated, were also planted. Observations were made after 9 to 15 days and are recorded in Table VIII.

TABLE VIII.—*Effect of 6 hours' presoaking followed by formalin 1:400 treatment on blackchaff bacteria on seeds placed on nutrient agar*

Experiment No.	Treatment.	Number of seeds used.	Percentage developing typical blackchaff colonies.	Percentage sterile.	Percentage contaminated with fungi or bacteria other than blackchaff.
I.	Inoculated seeds presoaked 6 hours, formalin 1:400 for 10 minutes, covered 6 hours	400	0.0	65.5	34.5
	Controls inoculated but not treated	160	72.0	19.3	8.7
II.	Inoculated seeds presoaked 6 hours, formalin 1:400 for 10 minutes, covered 6 hours	400	.0	87.3	12.7
	Controls inoculated but not treated	200	77.0	2.0	21.0
III.	Inoculated seeds presoaked 6 hours, formalin 1:400 for 10 minutes, covered 6 hours	800	.2	97.7	2.1
	Controls inoculated but not treated	400	98.7	1.3	.0
Summary.	Inoculated seeds presoaked 6 hours, formalin 1:400 for 10 minutes, covered 6 hours	1,600	.1	87.0	12.9
	Controls inoculated but not treated	760	86.6	5.9	7.5

Only 2 out of 1,600 inoculated seeds treated by the presoak method developed typical blackchaff colonies. The controls, which had been inoculated and dried two days, showed 86.6 per cent of the kernels developing the typical colonies when planted on the nutrient agar, thus demonstrating that the absence of growth in the treated seeds was due not to drying of the bacteria but to the treatment as practiced (Pl. 79, 80). The presoaking, then, while limiting to a striking degree retardation of seed growth and loss due to failure to germinate, does not reduce the effectiveness of the subsequent formalin treatment as a means of treating diseased seed. In fact, it tends to increase its efficiency in this respect, as will be brought out in the discussion.

EFFECT OF SIX HOURS' PRESOAKING FOLLOWED BY FORMALIN 1 TO 320 AND COPPER SULPHATE 1 TO 80 ON ARTIFICIALLY INFECTED WHEAT SEEDS PLANTED IN THE SOIL UNDER FIELD CONDITIONS

Several field tests were made with seeds of Currell, China, and Dietz varieties artificially infected with blackchaff bacteria, dried, and treated with formalin 1 to 320 and copper sulphate 1 to 80, after a presoaking of six hours. The percentages of infection in the young seedlings two to three weeks after planting are given in Table IX.

TABLE IX.—*Effect of presoak method of treatment on inoculated wheat seeds under field conditions*

Treatment.	Experiment of Aug. 9.			Experiment of Aug. 22.			Experiment of Sept. 7.		
	Variety of wheat used.	Isolation number of *Bact. translucens* var. *undulosum*.	Percentage of infection of seedlings.	Variety of wheat used.	Isolation number of *Bact. translucens* var. *undulosum*.	Percentage of infection of seedlings.	Variety of wheat used.	Isolation number of *Bact. translucens* var. *undulosum*.	Percentage of infection of seedlings.
Seeds soaked in bacterial suspension 20 minutes, dried, planted at same time as treated seeds below.	Currell.	[a] 850	92.6	Currell.	[a] 271–A	85.5	Currell.	[b] 213	68.9
	China..	[c] 318	90.1	China..	394	91.0	China..	271–A	82.0
	Dietz..	[c] 394	95.1	Dietz..	850	80.3	.....	.....	.....
Seeds soaked in bacterial suspension 20 minutes, dried overnight, soaked in water 10 minutes, covered 6 hours, soaked in formalin 1:320 for 10 minutes, covered 6 hours, dried, and planted.	Currell.	850	1.0	Currell.	271–A	.7	Currell.	213	.0
	China..	318	.5	China..	394	.4	China..	271–A	.5
	Dietz..	394	.3	Dietz..	850	.0	.....	.....	.....
Seeds soaked in bacterial suspension 20 minutes, dried overnight, soaked in water 10 minutes, covered 10 hours, soaked in copper sulphate 1:80 for ½ hour, then in milk of lime 1:80 a moment, dried, and planted.	Currell.	850	.8	Currell.	271–A	.9	Currell.	213	.8
	China..	318	1.5	China..	394	.3	China..	271–A	.6
	Dietz..	394	.9	Dietz..	850	.0	.....	.....	.....

[a] From Kansas. [b] From Colorado. [c] From Montana.

Bacterial infection was prevented to a very marked degree in the treated seeds. The controls, infected with five isolations of *Bacterium translucens* var. *undulosum* from different localities, showed from 69 to 95 per cent infection, considerably more than would usually occur in naturally diseased seed, owing to the heavy artificial inoculation and brief drying period before planting. Infection of these seeds, heavily inoculated as they were, was reduced from 0 to 1.5 per cent by the presoak method, used with both formalin and copper sulphate. The application of this method, then, to the control of blackchaff on the farm is evident. The only doubt that can be entertained is in cases where the bacteria have penetrated the seed coats. Fortunately, in most such cases at least, the seeds are more or less shriveled and of light weight so that they may be screened out in advance of treatment.

RESULTS OF PRESOAK TREATMENTS ON NATURALLY INFECTED WINTER WHEAT PLANTED IN THE WHEAT FIELDS OF IOWA AND KANSAS

The first extensive field trial of this method was made in 1919 at three places in the middle western wheat belt—Ames, Iowa, and Hays and Abilene, Kans.,[1] where Kharkoff and Kanred from infected fields, screened and unscreened, was treated and drilled in after two to nine days' drying. The treatments used were (1) presoak copper-sulphate treatment, in which seeds were soaked 10 minutes in water, covered 6 hours, soaked ½ hour in copper sulphate 1 to 80, limed, dried, and planted; (2) presoak formalin treatment, in which the seeds were soaked 10 minutes in water, covered 6 hours, soaked 10 minutes in formalin 1 to 320, covered 6 hours, dried, and planted. Notes on the amount of infection on the seedlings were first made four to seven weeks after planting, since infection at this time would represent mostly primary infections due to diseased seed, before general dissemination from infection centers could set in. The results are summarized in Table X.

TABLE X.—*Preliminary results of presoak treatments of infected winter wheat in the Middle West, 1919*

Locality.	Wheat variety.	Treatment.	Size of plot.	Date treated, 1919.	Date planted, 1919.	Date observed, 1919.	Number of plants examined.	Number of plants infected.	Percentage of infection.
Ames, Iowa	Kanred [a]	No treatment, unscreened.	1/20 acre.	.....	Sept. 27	Nov. 7	312	28	8.9
	..do.....	Presoak copper sulphate treatment, unscreened	...do....	Sept. 18	...do...	...do...	360	2	.6
	..do.....	Presoak formalin treatment, unscreened	...do....	...do...	...do...	...do...	343	0	.0
Hays, Kans.	Kharkoff.	No treatment, screened.	1/10 acre [b]	.....	Sept. 24	Nov. 10	218	17	7.8
	Kanred..	.....do.....	...do [b] ...	.....	...do...	...do...	250	23	9.2
	Kharkoff.	Presoak formalin treatment screened.	...do....	Sept. 22	...do...	...do...	312	0	.0
	Kanred..	..do.....	...do....	...do...	...do...	...do...	321	1	.3
Abilene, Kans	..do.....	No treatment, screened.	45 acres..	.....	Oct. 6 to 10	Nov. 9	200	23	11.5
	..do.....	Presoak formalin treatment screened.	15 acres..	Oct. 1	...do...	...do...	360	[c] 0	.0

[a] A very susceptible variety.
[b] Part of main field.
[c] One diseased plant was found; but, judged by its advanced stage of growth, it was a volunteer and was therefore not from the treated seeds.

The seedlings at the time of observation bore two to five leaves, with infection visible on the first leaf of diseased plants verified by microscopic examination. In untreated areas, from 7.8 to 11.5 per cent infection was present; in treated areas, from 0 to 0.6 per cent, as shown in

[1] The author is indebted to Dr. I. E. Melhus, at Ames, and to Mr. Swanson, at Hays, for cooperation and assistance at these localities.

the table, indicating so far a satisfactory degree of control under actual field conditions through the use of the presoak method as formulated.

Plants collected from the western experimental plots March 27 to April 3, 1920, were examined microscopically for the presence of oozing bacteria in suspected blackchaff lesions and in dead leaves. Platings were made later from similar lesions where abundant oozing bacteria were found, and these developed the typical blackchaff colonies. Table XI summarizes the results obtained.

TABLE XI.—*Condition of western experimental plots in the spring of 1920*

Locality.	Treatment.	Date observed, 1920.	Number of plants examined.	Number with bacteria oozing from cut sections.	Percentage of infection.
Abilene, Kans.	Kanred wheat, untreated, 45 acres.	Mar. 27	212	46	21.7
	Presoak formalin treated plot,[a] 15 acres; plants collected from half of plot farthest from untreated area.	...do.....	185	9	4.8
	Same treated plot; plants collected from other half, near untreated area.	...do.....	196	12	6.1
Hays, Kans.	Kharkoff wheat, untreated.....	Mar. 30	141	24	17.0
	Kharkoff wheat, presoak formalin treated plot.[a]	...do.....	231	7	3.0
	Kanred wheat, untreated.....	...do.....	192	49	25.5
	Kanred wheat, presoak formalin treated plot.[a]	...do.....	218	9	4.1
Ames, Iowa.....	Kanred wheat, untreated.....	Apr. 3	285	53	18.5
	Kanred wheat, presoak formalin treated plot.[a]	...do.....	221	6	2.7
	Kanred wheat, presoak copper-sulphate treated plot.[b]	...do.....	236	5	2.1

[a] Seeds presoaked 6 hours, then treated with formalin 1 to 320 for 10 minutes, drained, covered 6 hours and dried.

[b] Seeds presoaked 6 hours, then treated with copper sulphate 1 to 80 for half hour (soaked), and dried after dipping a moment in milk of lime.

A marked increase in blackchaff was observed in the untreated plots, evidently due to wind and rain spreading the disease during the resumption of growth. The spreading effect was especially noted in the Abilene plots where the treated area adjoins the untreated. Other treated areas at Hays and Ames, more isolated, show from 2 to 4 per cent of infection, as compared with 17 to 25.5 per cent in untreated plots.

Observations made at Hays and Abilene, Kans., in the latter part of May, 1920, are summarized in Table XII. At Abilene the plants were 1 to 2 feet tall, at Hays over 2 feet high. Heads had not yet emerged. Microscopic examination and confirmation of diagnoses by platings were

made as previously indicated. Typical yellow colonies of the blackchaff organism, concentrically striated by oblique light, were readily obtained in poured plates from blackchaff leaf lesions, which at this stage appeared characteristically as brown, water-soaked linear areas, narrow and extending for various lengths along the edges or centers of the second, third, or fourth leaves from the top, with clouds of oozing bacteria in cut sections. Septoria was also found in the oldest leaves, distinguished by wider lesions and characteristic black dots of pycnidia.

TABLE XII.—*Condition of experimental plots in May, 1920*

Locality and date.	Plot.	Number of plants examined.	Number with bacteria oozing from cut sections.	Percentage of infection.
Abilene, Kans., May 15, 1920.	Kanred, untreated	312	87	27.8
	Kanred, western area, presoak formalin treated.	386	26	6.7
Hays, Kans., May 22, 1920.	Kanred, untreated	293	98	33.4
	Kanred, presoak formalin treated	356	33	9.2
	Kharkoff, untreated	266	72	27.0
	Kharkoff, presoak formalin treated	298	22	7.3

There is an evident increase in the amount of secondary infection during April and May. It was also observed that most of the lesions on leaves from treated plots were small, 2 to 8 mm. long, consisting of from 1 to 3 spots on the second or third leaf from the top, and were evidently fairly recent infections. Leaves from control plots showed similar lesions but also a larger proportion of more advanced lesions up to 30 mm. long on the older leaves. No lesions were observed in the young heads, which were still inclosed in the sheath.

EFFECT OF MODIFYING THE TREATMENT PERIODS UNDER FIELD CONDITIONS

A shortening of the entire treatment period appeared desirable after field experience with the method so far described, mainly for the purpose of facilitating drying after treatment. Three greenhouse germination experiments were made with Currell wheat seed, using a shorter presoak time and a longer (varying) soak in formalin 1 to 320, followed by very short periods during which the seeds were kept moist, the entire process covering various periods from 5½ to 8 hours as outlined in figure 7.

Formalin treatments involving a soaking longer than previously used—that is, of 15 to 30 minutes—followed by immediate drying or involving a short moist period of 1 to 3 hours decreased the germination considerably. The same treatments preceded by a 5-hour presoak (in one case a 6-hour presoak) resulted in no injury whatever to germination and in fact caused distinct acceleration. The effect of the various periods upon germination was determined for infected wheat seed also.

Currell wheat seed was inoculated with a bacterial suspension of *Bacterium translucens* var. *undulosum*, isolation No. 850, treated with formalin for the periods given in Table XIII, planted outdoors, and the percentage of infected seedlings determined 27 days after planting.

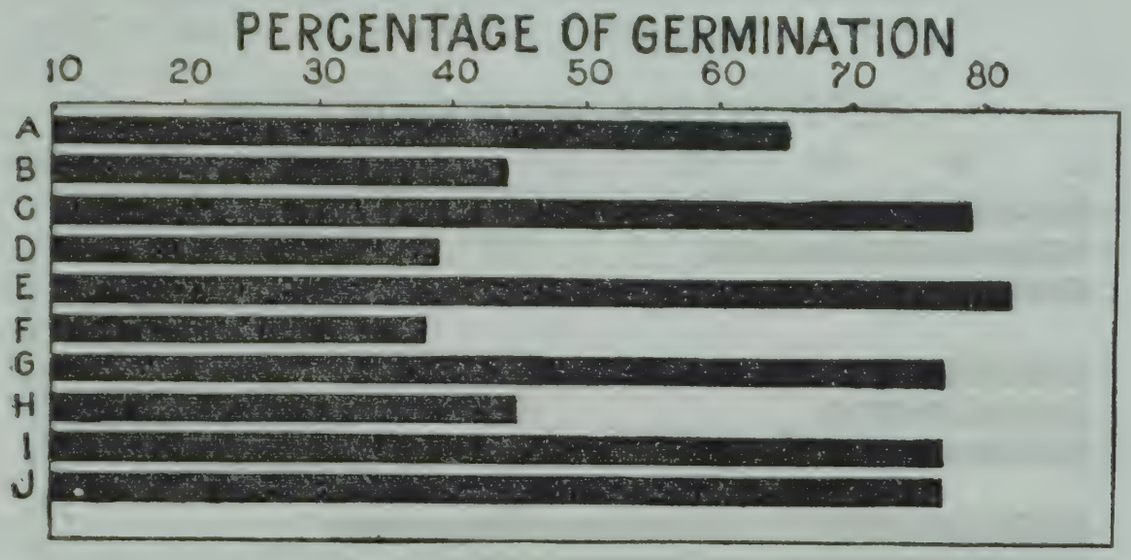

FIG. 7.—Graph showing effect of formalin 1 to 320 treatments for various periods, with and without presoaking: A, control, untreated; B, seeds soaked in formalin 1 to 320 for 15 minutes drained, covered 2 hours, dried overnight, and planted; C, seeds soaked in water 10 minutes, covered 5 hours, then treated with formalin as in B; D, seeds soaked in formalin 1 to 320 for 15 minutes, drained, covered 3 hours, and dried overnight; E, seeds soaked in water 10 minutes, covered 5 hours, then treated with formalin as in D; F, seeds soaked in formalin 1 to 320 for 30 minutes, drained, covered 1 hour, and dried overnight; G, seeds soaked in water 10 minutes, covered 5 hours, then treated with formalin as in F; H, seeds soaked in formalin 1 to 320 for 30 minutes, drained, and dried overnight; I, seeds soaked in water 10 minutes, covered 5 hours, then treated with formalin as in H; J, seeds soaked in water 10 minutes, covered 6 hours, then treated with formalin as in H. Records of germination were made on the sixth day after planting and are the averages of three experiments.

TABLE XIII.—*Effect of shortened presoak method of treatment on infected wheat seed under field conditions*

Treatment.	Number of plants examined.	Number of plants infected.	Percentage of infection after 27 days.
Inoculated seeds dried and planted without further treatment	221	40	18.2
Inoculated seeds soaked in water 10 minutes, drained, covered 5 hours, soaked in formalin 1:320 for 15 minutes, covered 2 hours, dried, and planted	215	4	1.8
Inoculated seeds soaked in water 10 minutes, drained, covered 5 hours, soaked in formalin 1:320 for 15 minutes, covered 3 hours, dried, and planted	196	1	.5
Inoculated seeds soaked in water 10 minutes, drained, covered 5 hours, soaked in formalin 1:320 for 30 minutes, covered 1 hour, dried, and planted	231	0	0
Inoculated seeds soaked in water 10 minutes, drained, covered 5 hours, soaked in formalin 1:320 for 30 minutes, dried, and planted	211	2	.9
Inoculated seeds soaked in water 10 minutes, drained, covered 6 hours, soaked in formalin 1:320 for 30 minutes, dried, and planted	246	3	1.2

The best control in this experiment was obtained with a presoak of 5 hours, followed by 30 minutes' formalin soak, then covering 1 hour. Such a process, requiring 6½ hours in all, would be particularly desirable because of the ease in subsequently drying the seeds by spreading them in the sun on the day of treatment, Further field repetition of this experiment, which was suspended at this time by the advent of winter,

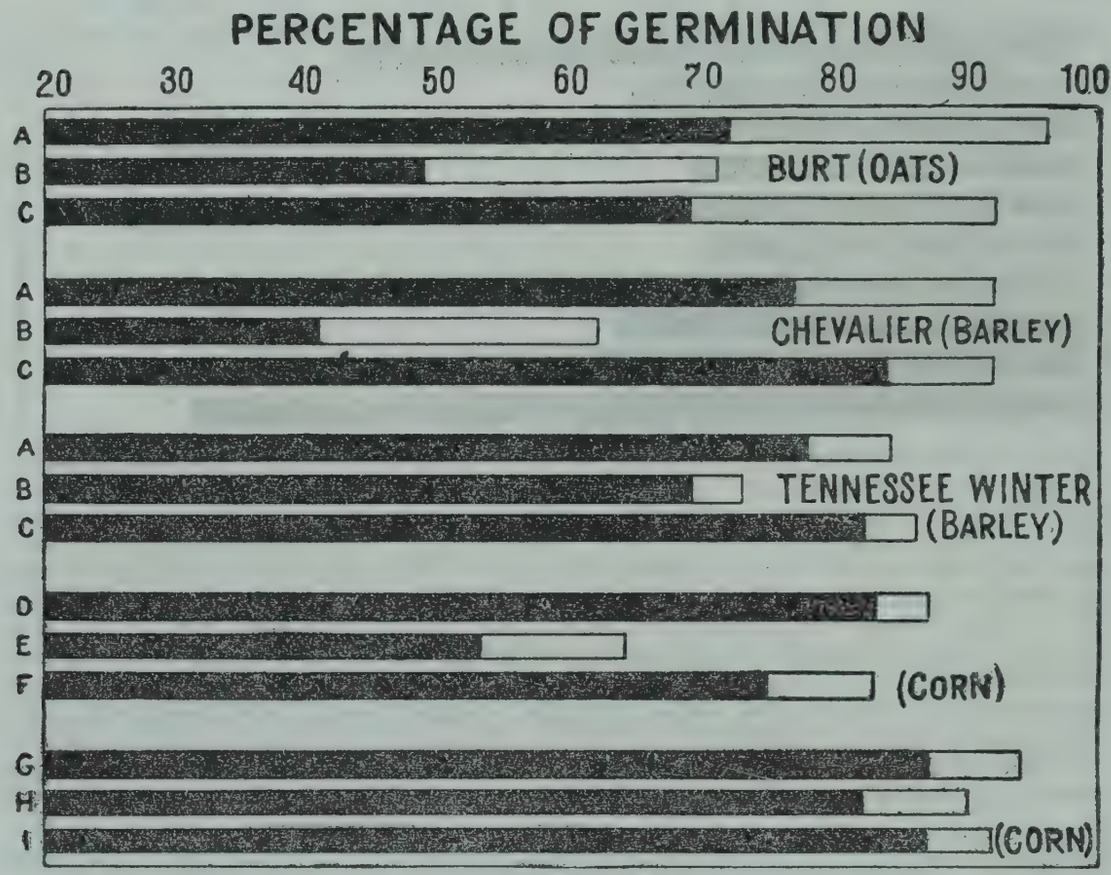

FIG. 8.—Graph showing effect of formalin 1 to 320 and 1 to 200 on germination of corn, barley, and oats with and without presoaking: A, controls ; B, seeds soaked in formalin 1 to 320 for 10 minutes, drained, kept moist (covered) 6 hours, dried overnight, and planted; C, seeds soaked in water 10 minutes, drained, and kept moist (covered) 6 hours. then soaked in formalin 1 to 320 for 10 minutes, drained, and kept moist (covered) 6 hours, dried overnight, and planted; D and G, controls; E and H, seeds soaked in formalin 1 to 200 for 10 minutes, drained, kept moist (covered) 4 hours, dried overnight, and planted; F, seeds soaked in water 10 minutes, drained, kept moist (covered) 10 hours, then soaked in formalin 1 to 200 for 10 minutes, drained, kept moist (covered) 4 hours, dried overnight, and planted; I, seeds soaked in water 10 hours, drained thoroughly a few minutes, then soaked in formalin 1 to 200 for 10 minutes, drained, kept moist (covered) 4 hours, dried overnight, and planted. Records of the germination were made on the fifth and seventh days after planting in the greenhouse..

is necessary, however, before definite recommendations on this modification can be made.

EFFECT OF THE PRESOAK METHOD ON OTHER CEREALS

The uniform results obtained on nine different varieties of wheat by the presoak method of treatment with formalin and copper sulphate and a consideration of the underlying principles governing its salutary action, as will be discussed later, suggested that it might be generalized for the treatment of all seed-transmitted diseases of economic importance amen-

able to control by formalin and copper sulphate. So far, this method has been tested on the germination of oats, barley, and maize with results similar to those obtained for wheat. Copper-sulphate injury can be prevented for Tennessee winter barley as shown above. The results thus far obtained with the presoak method of treatment, using formalin 1 to 320 on oats and barley and formalin 1 to 200 on maize, are given in figure 8. Oats and barley were soaked in water 10 minutes, drained, and kept moist 6 hours, then soaked in formalin 1 to 320 for 10 minutes, and covered 6 hours. Maize, which absorbs water much more slowly than wheat, oats, or barley and is also less susceptible to formalin injury, was given a 10-hour presoak—that is, 10 minutes in water, draining and covering for 10 hours, followed by 4 hours' formalin 1 to 200 treatment.

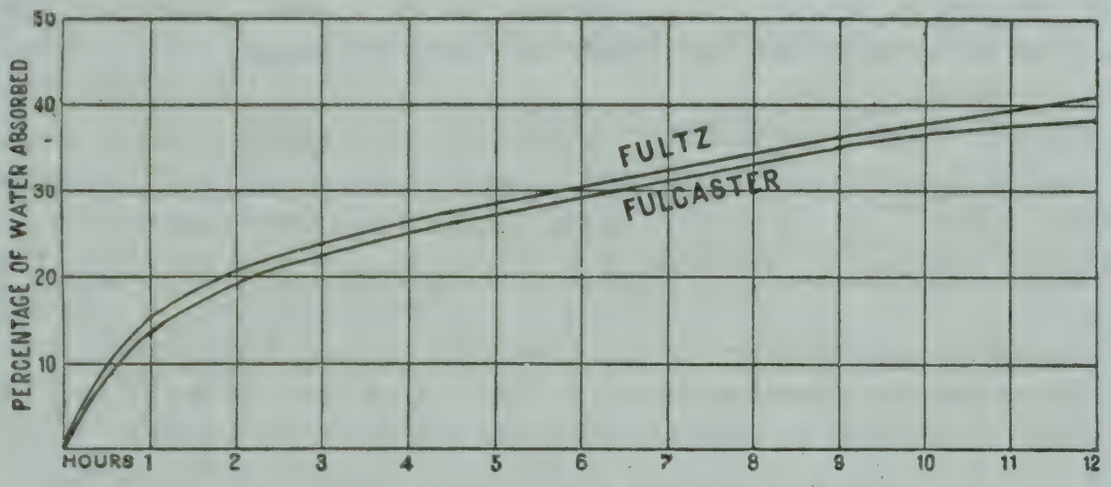

FIG. 9.—Curve showing rate of absorption of water by dry wheat seeds.

In another case it was given a 10-hour actual soaking in water, followed by the treatment.

The presoak method is evidently applicable to these cereals also, as a means of preventing seed injury due to disinfectants (Pl. 81, 82); and the possibility of its application for other kinds of seeds is obvious.

GENERAL DISCUSSION

As a result of these experiments several facts stand out clearly. First, in all cases, with each variety of wheat, barley, oats, and maize tested, the presoak method minimized or eliminated the injury to seed germination due to the use of formalin and copper sulphate. Second, as shown in the illustrations, a marked stimulation of growth was usually produced. Third, the presoak method proved fully efficient as a means of destroying or preventing the growth of the bacteria of the blackchaff disease borne on the seed and can undoubtedly be applied for the prevention of other diseases. Fourth, the method is simple and adapted to field conditions, since any farmer can apply it.

The cause of the first-mentioned effect of the presoak treatment may be partly accounted for upon an analysis of figure 9. This represents the rate of absorption of water by 10 gm. each of dry seeds of two wheat

varieties, soaked 10 minutes in water, drained, and kept moist for 12 hours, with periodical weighings after blotting off all surface water each time. The excess weight above 10 gm. represents the amount of water absorbed. The curve rises rapidly in the first 3 hours, then slows down somewhat to a more gradual rise. At the end of 6 hours, about 30 per cent by weight of water has been absorbed; during the next 6 hours, about 10 per cent more is absorbed. The 6 hours' presoaking, as practiced, consequently impregnates the cell walls and cells of the seed with water, increasing the size and adding about 30 per cent by weight to the seeds. The next 6 hours' treatment with water containing formalin in solution adds only one-third as much more; and the formalin solution as it diffuses into the seeds is consequently greatly diluted by the amount of water already present in the tissues. Moreover, the amount of formalin solution which can enter the tissues in the 6 hours after presoaking is only one-third of what enters during a 6-hour formalin treatment without presoaking. Should the subsequent formalin treatment last much longer than 6 hours, an equilibrium would finally be established between the strength of solution within the seeds and that on the surface, resulting in both cases in a solution weaker than the original, in accordance with the laws of diffusion of dissolved substances. Removing the presoaked seeds after 6 hours' formalin treatment leaves them with a solution content considerably more dilute than that finally present in air-dry seeds directly treated with the full-strength solution; consequently the weakened solution within the presoaked seeds resulted in a very marked decrease in seed injury, as observed throughout the experiments.

As for the stimulation observed in presoaked seeds, this may be due partly or wholly to the well-known stimulating effect of a toxic agent in minimum dose, such as would finally be present in the presoaked seeds.

In considering the effect of the presoak method on the blackchaff bacteria on the seed coat, the dominant factor involved is the established principle that microorganisms in an active vegetative condition are more susceptible to the action of destructive agents than when dormant. Presoaking the seeds, and consequently the bacteria on them, for a period of six hours at room temperature causes the bacteria to begin to resume vegetative activity before seed germination commences, because the moisture and temperature conditions are ample for bacterial growth and division to begin during this period. Subsequently exposed to the direct action of the formalin solution applied full strength to the surface of the seeds, the bacteria are naturally much more susceptible to destruction in this active condition. As a result, the disinfectant must act with greater efficiency than in the usual treatment, where it acts on dried and dormant bacteria. The six hours' presoak, on the other hand, is not sufficient to cause wheat-seed germination, which would produce a condition extremely susceptible to formalin injury.

The method of treatment discussed has, therefore, a two-fold advantage. On the one hand, wheat-seed injury due to the use of formalin and copper sulphate is eliminated or reduced to a minimum. On the other hand, the blackchaff organisms on the seed coats are rendered particularly sensitive to the action of the disinfectant by being previously brought into a vegetative condition.

The same physiological principles discussed above should hold true for the general problem of seed treatment for various seed-borne pathogens. The consistency of the results obtained by this method with nine varieties of wheat and with other cereals, using formalin and copper sulphate, indicates the possibility of the use of the presoak method with other kinds of seeds as a means of minimizing or preventing seed disinfectant injury. Similarly, other pathogenic organisms, bacteria, or fungus spores, may be stimulated by the presoak method into increased susceptibility to the disinfectant.

The presoak method of seed treatment with chemical disinfectants may be formulated for general purposes as consisting of two parts: First, the presoak period, in which seeds are soaked in water for 10 minutes, drained, and kept covered and moist for a definite period of time, which is 6 hours for wheat, barley, and oats and 10 to 18 hours for maize—in no case sufficient to begin seed germination; second, the disinfectant-treatment period immediately following, in which the disinfectant is applied exactly as now practiced. The relative time of the presoak and subsequent treatment for other diseases, probably varying with each kind of seed and pathogen, is dependent on the following factors:

(1) Susceptibility of the kind of seed used to the disinfectant.
(2) Susceptibility of the pathogen to the disinfectant.
(3) Rate of absorption of water by the seeds.
(4) Time at which seed germination begins.
(5) Time at which vegetative activity of the pathogen begins.

A proper balance of these factors must be obtained, such that the optimum seed germination and the optimum germicidal efficiency are secured, as reported for the blackchaff disease of wheat.

The length of the presoak period should not exceed half or two-thirds of the period necessary for seed germination to begin, since germination before treatment with the disinfectant would result in extreme sensitiveness to injury. On the other hand, the pathogen, especially if bacterial in nature, usually has a much shorter germination period, which should come within the limit of the time of presoak and thus render it susceptible long before the seed has begun to germinate. The period necessary for the absorption of about 30 per cent by weight of water appears to be sufficient, and in the case of the cereals so far tried seems to counteract disinfectant injury. In wheat, oats, and barley this is five to six hours. The length of time necessary for other kinds of seeds to absorb about 30 per cent of water is suggested as the presoak period when not conflicting with the other factors involved.

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Actual soaking in water throughout the presoak period does not appear to be so favorable for wheat-seed treatment as the procedure of soaking 10 minutes in water and merely keeping moist for 6 hours.

For use in farm practice this method does not involve any radical change in present procedure other than to keep the seeds moist for a definite time before treating. In controlling the blackchaff disease of wheat, seeds should first be screened to remove shriveled grain. Then the seeds in sacks or bags, in quantities of not more than ½ bushel each, can be soaked early in the morning in water for 10 minutes, drained, and set away in the bags while moist. Six hours later, at about noon, the seeds should be thoroughly soaked for 10 minutes in a formalin solution of 1 pound to 40 or 50 gallons of water, drained, and left in the bags for 6 hours. In the evening the seeds should be spread out to dry overnight and are ready for planting the next morning.

The use of formaldehyde vapor recently proposed by Thomas (*10*) for seed treatment, while eminently suitable for the disinfection of small seed lots which are not to be planted immediately, is open to the serious objection of lack of penetration throughout the seed mass and is not so well adapted as the presoak method for the treatment of seeds in large masses in farm practice. His experiments indicate that the vapor, while efficient on surface seeds, does not reach seeds at a depth of ½ inch, so that these remain as badly contaminated as untreated controls. In the presoak method, every seed is surrounded by a film of the disinfectant acting on the pathogens which previously have been brought into a vegetative condition by the long exposure to moisture at room temperature.

The presoak method used with copper sulphate, if efficient for controlling the cereal smuts,[1] would be particularly adapted for the grain sections of the Northwest. Extensive soil infection in this area renders the use of copper sulphate preferable to formalin because of its residual germicidal effect; and, as here shown, copper-sulphate injury may be prevented by a 6-hour presoak.

The general application of the presoak method, extremely simple in itself, to the formalin and copper-sulphate treatments of the cereal diseases amenable to control by seed disinfection should, if the results here recorded are confirmed for other diseases by subsequent careful

[1] A paper by Heald (*2*), first brought to the writer's attention in Nov. 14, 1919, when these experiments were completed and the manuscript was prepared for the press, shows some interesting data on a somewhat similar method used for treatment of barley smut. Heald soaked barley seeds in water 4 hours, covered them 8 hours longer, then treated them with formalin 1 to 288 for 10 minutes and then kept them covered 2 hours. No statement as to the manner of arriving at the use of this procedure is made. His figures indicate for this treatment (1) less injury to germination than for any other formalin treatment which he used, (2) effective control of barley smut—0.93 per cent smut in a plot treated in this manner and 0.73 per cent in a somewhat similarly treated copper-sulphate plot compared to an average of 33.02 per cent smut in three untreated plats. This corroborates for barley smut the work reported on blackchaff with the presoak method. Heald does not appear to have followed up his work, which was clearly a rule of thumb, nor did he recommend this particular method for general use with other methods. He made no allowance for loss in number of seeds per bushel through swelling, otherwise he must have obtained results which would have indicated to him clearly the importance of the method, since he must then have obtained larger yields than by any other method which he used. Moreover, my method differs from Heald's in that it gives only a short plunge in water rather than a long one, and this is an important difference.

research, result in a saving of a large percentage of seeds destroyed by the usual treatments or delayed in germination and thus longer exposed to the attack of soil fungi, giving at the same time a more efficient germicidal action on the pathogens involved.

SUMMARY

(1) The use of formalin and copper sulphate as now practiced usually causes retardation and injury to seed germination.

(2) Greenhouse and field experiments here reported have shown that this detrimental effect can be eliminated for standard varieties of wheat by allowing the seeds to absorb water for six hours before submitting them to the treatment with formalin or copper sulphate. Soaking for a short period (10 minutes) and covering for 6 hours, here designated the presoak method, is better than leaving in water for 6 hours. Similar results were obtained in experiments with barley, oats, and corn.

(3) The saturation of the seed cells and cell walls with water during the presoak period appears to be the factor counteracting the injurious effect on seed germination by diluting the disinfectant beyond the point of injury as it diffuses into the tissues and also by considerably decreasing the amount of water plus disinfectant solution which may enter the tissues after presoaking as compared to what may enter without any presoaking.

(4) Actual stimulation of germination has been observed repeatedly in presoak-treated seeds, a factor which by shortening germination minimizes the danger of exposure to the attack of soil organisms during this susceptible period.

(5) The bacterial blackchaff disease of wheat can be controlled without any injury to seed germination by a 6-hour presoak of surface-infected seeds in water followed by a 6-hour treatment with formalin 1 to 400 in the manner prescribed.

(6) In practice, wheat seeds after being screened should be soaked with water for 10 minutes at about 6 o'clock in the morning, drained, covered, and set away moist till noon, then soaked with formalin 1 to 400 for 10 minutes, drained, covered, and set away moist till 6 o'clock in the evening, when they should be spread out to dry overnight to be ready for planting the next day.

(7) In planting, an allowance must always be made for the fact that there are fewer treated seeds in a bushel than there are of dry untreated ones. In general, it is recommended to sow about 25 per cent more bulk than is usual of the dry grain, otherwise fewer seeds will be actually planted and the yield will be reduced correspondingly.

(8) The use of the presoak method tends to increase the efficiency of the disinfectant, in that the presoaking stimulates dormant bacteria and possibly fungi into vegetative activity, thereby rendering them extremely susceptible to the subsequent action of the disinfectant.

(9) The general use of the presoak method of treatment in farm practice for other diseases involves no radical change in present procedure,

the only deviation being to keep the seeds moist for a definite period before giving them the disinfectant treatment.

(10) In applying the principles here utilized to other kinds of seeds, the determination of the lengths of the two parts of this method—(1) the presoak period, (2) the subsequent disinfectant treatment period—must be governed by the following factors: (a) the rate of absorption of water by the seeds, (b) the susceptibility of the seeds and pathogens to the disinfectant, and (c) the respective periods necessary for the beginning of seed germination and of vegetative activity of the pathogen. In no case must the presoak period be continued until seed germination begins. The length of time necessary for the seeds to absorb about 30 per cent of their weight of water is suggested as the length of the presoak period when not conflicting with the other factors involved.

(11) The presoak method of treatment, as here formulated, is proposed as a basis for the reinvestigation of practical seed treatment for all seed-transmitted diseases of economic importance amenable to control by formalin and copper sulphate as a means of eliminating seed injury and at the same time increasing germicidal efficiency.

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(6)———
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(7) ———
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PLATE 69

Relative injury to wheat-seed germination caused by short and long formalin treatments:

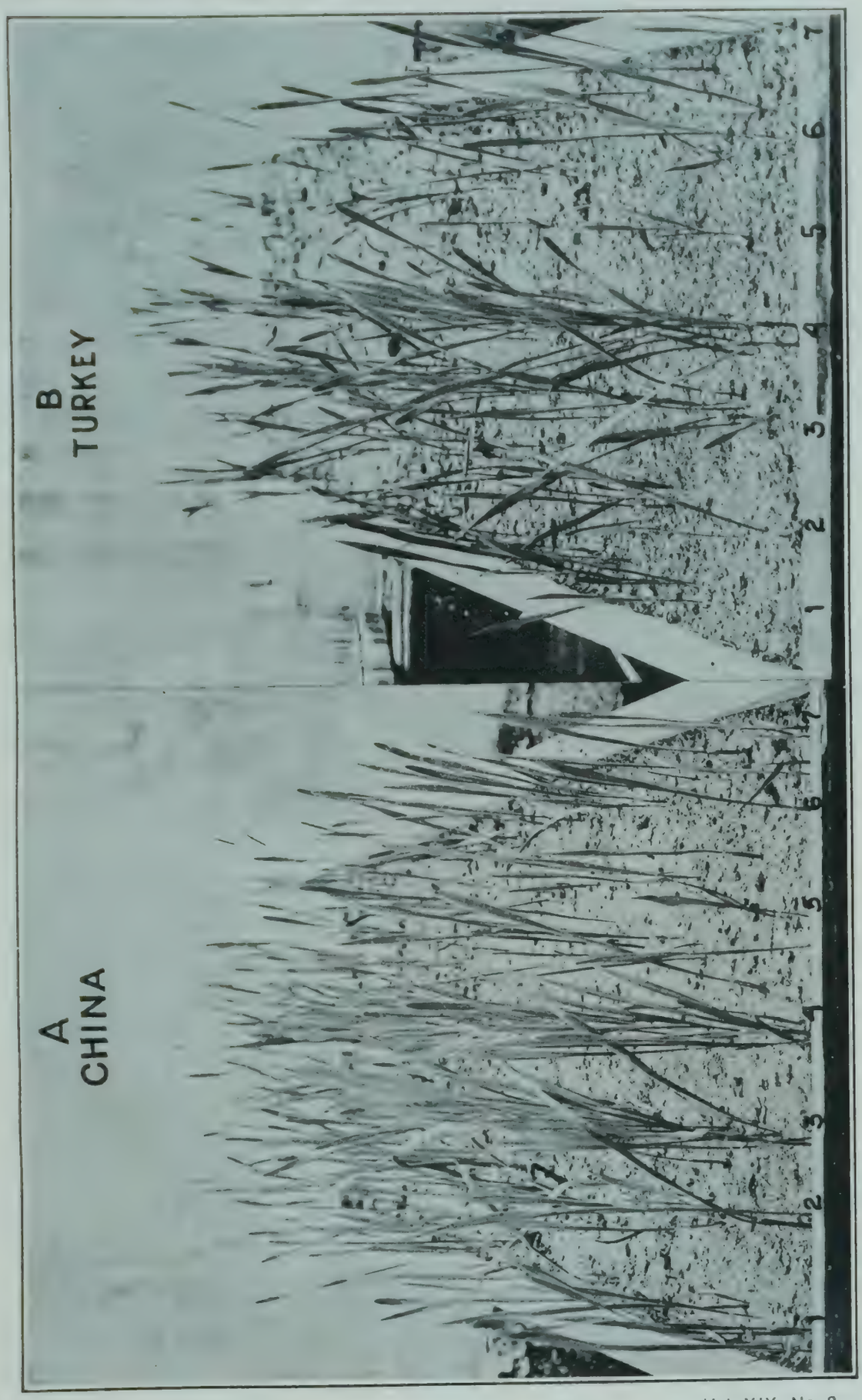
A.—Effect of formalin 1 to 400 and 1 to 200 treatment for 3, 6, and 12 hours on China variety:

Row 1, formalin 1 to 400 for 3 hours, 56 per cent germination;
Row 2, formalin 1 to 400 for 6 hours, 53 per cent germination;
Row 3, formalin 1 to 400 for 12 hours, 74 per cent germination;
Row 4, control, 78 per cent germination;
Row 5, formalin 1 to 200 for 3 hours, 39 per cent germination;
Row 6, formalin 1 to 200 for 6 hours, 37 per cent germination;
Row 7, formalin 1 to 200 for 12 hours, 57 per cent germination.

B.—Effect of formalin 1 to 400 and 1 to 200 treatment for 3, 6, and 12 hours on Turkey variety:

Row 1, formalin 1 to 400 for 3 hours, 42 per cent germination;
Row 2, formalin 1 to 400 for 6 hours, 48 per cent germination;
Row 3, formalin 1 to 400 for 12 hours, 50 per cent germination;
Row 4, control, 56 per cent germination;
Row 5, formalin 1 to 200 for 3 hours, 23 per cent germination;
Row 6, formalin 1 to 200 for 6 hours, 17 per cent germination;
Row 7, formalin 1 to 200 for 12 hours, 34 per cent germination.

Note increased vigor and germination of 12–hour treated seeds compared with 3-hour or 6–hour treated seeds.


A
CHINA
B
TURKEY

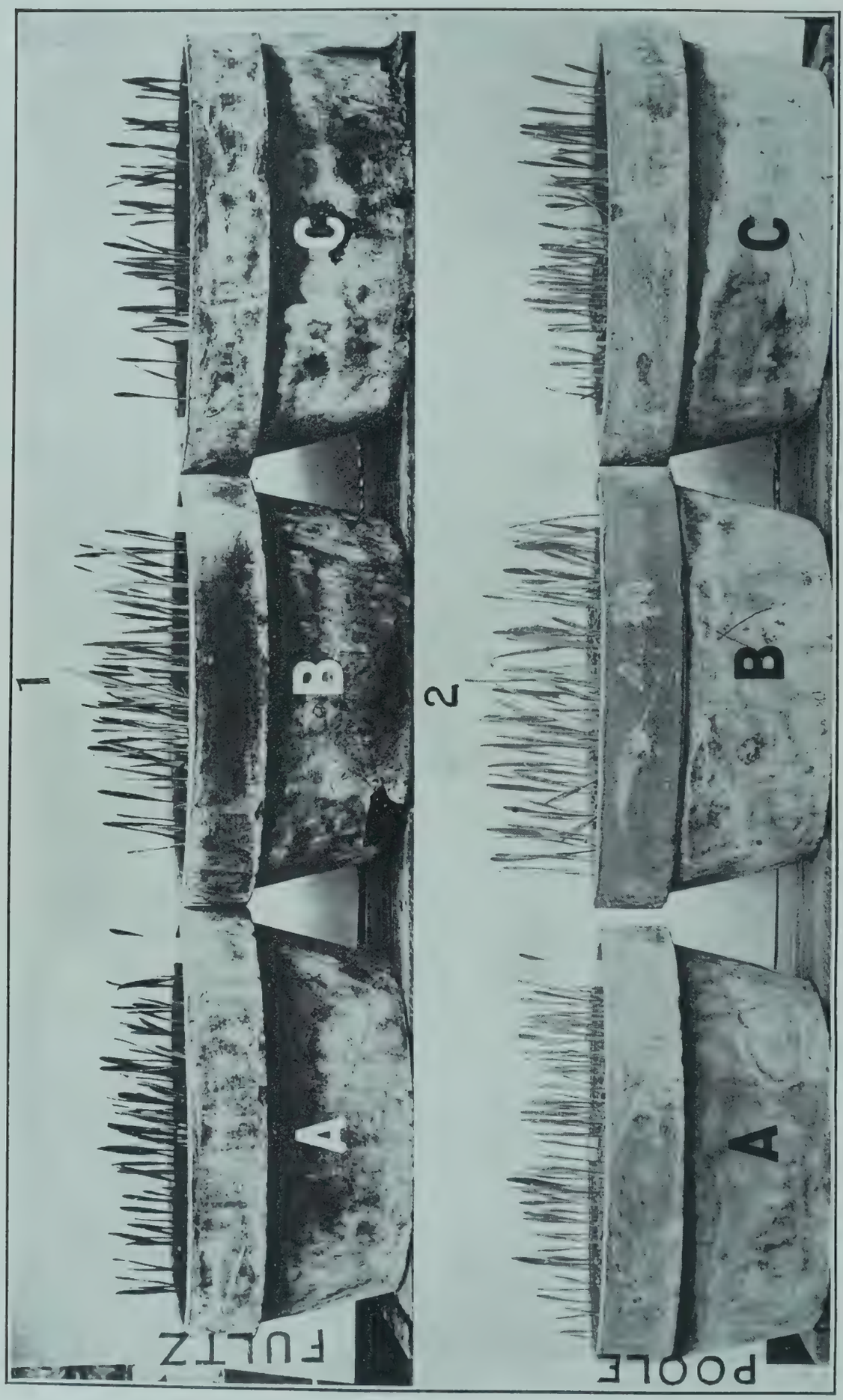

1
A
B
C
FULTZ
2
A
B
C
POOLE

PLATE 70

Effect of formalin 1 to 400 treatment for 6 hours, with and without 6-hour presoak:

1. Fultz wheat: A, control, 76 per cent germination; B, seeds presoaked 6 hours, then formalin 1 to 400 for 6 hours, 79 per cent germination; C, seeds treated with formalin 1 to 400 for 6 hours, not presoaked, 57 per cent germination, plants dwarfed.

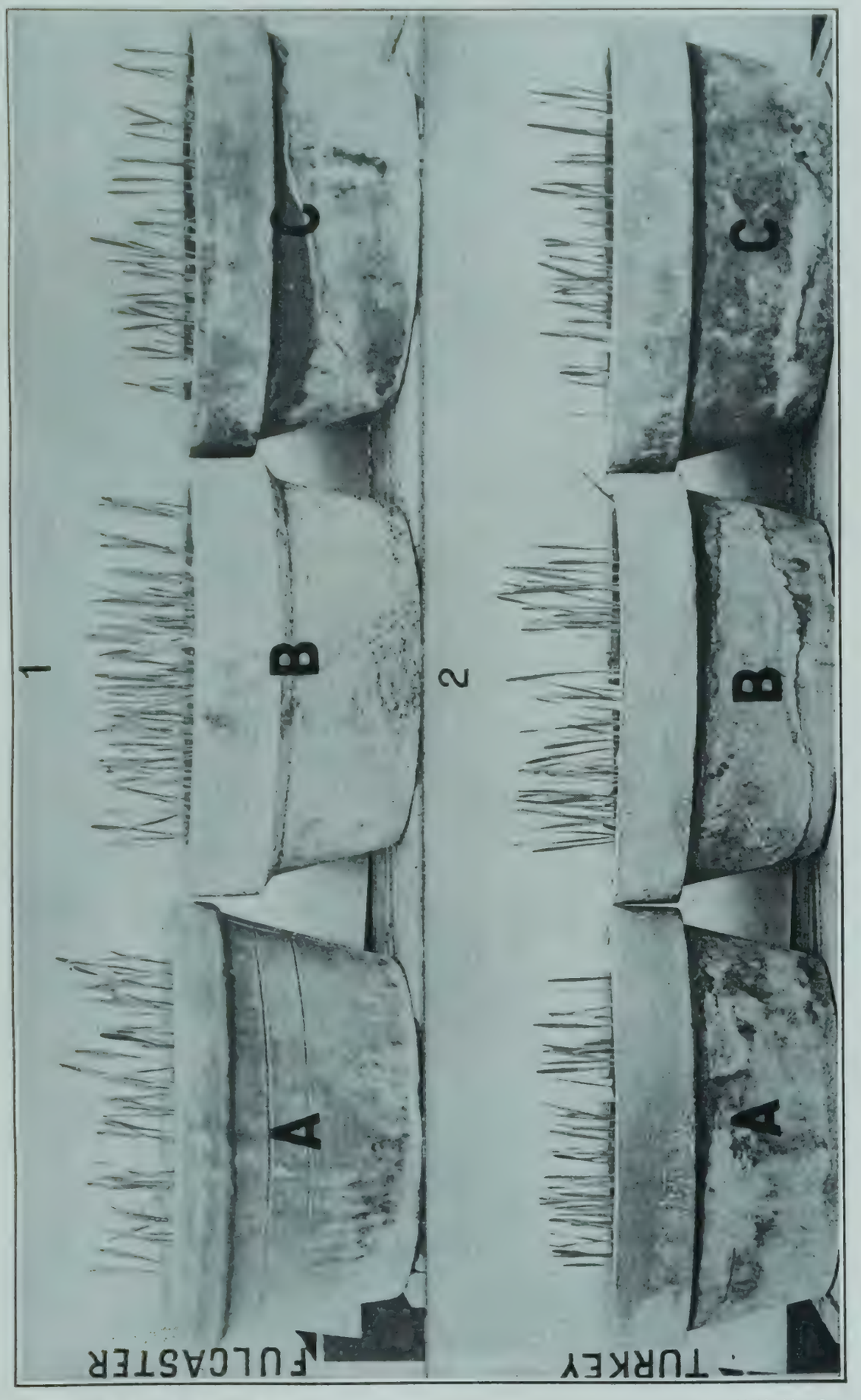
2. Poole wheat: A, control, 90 per cent germination; B, seeds presoaked 6 hours, then formalin 1 to 400 for 6 hours, 89 per cent germination; C, seeds treated with formalin 1 to 400 for 6 hours not presoaked, 67 per cent germination, plants dwarfed.

PLATE 71

Effect of formalin 1 to 400 treatment for 6 hours, with and without 6-hour presoak:

1. Fulcaster wheat: A, control, 71 per cent germination; B, seeds presoaked 6 hours, then formalin 1 to 400 for 6 hours, 83 per cent germination; C, seeds treated with formalin 1 to 400 for 6 hours, not presoaked, 54 per cent germination, plants dwarfed.

2. Turkey wheat: A, control, 61 per cent germination; B, seeds presoaked 6 hours then formalin 1 to 400 for 6 hours, 68 per cent germination; C, seeds treated with formalin 1 to 400 for 6 hours without presoaking, 50 per cent germination, plants dwarfed.


1
A
B
C
FULCASTER
2
A
B
C
TURKEY

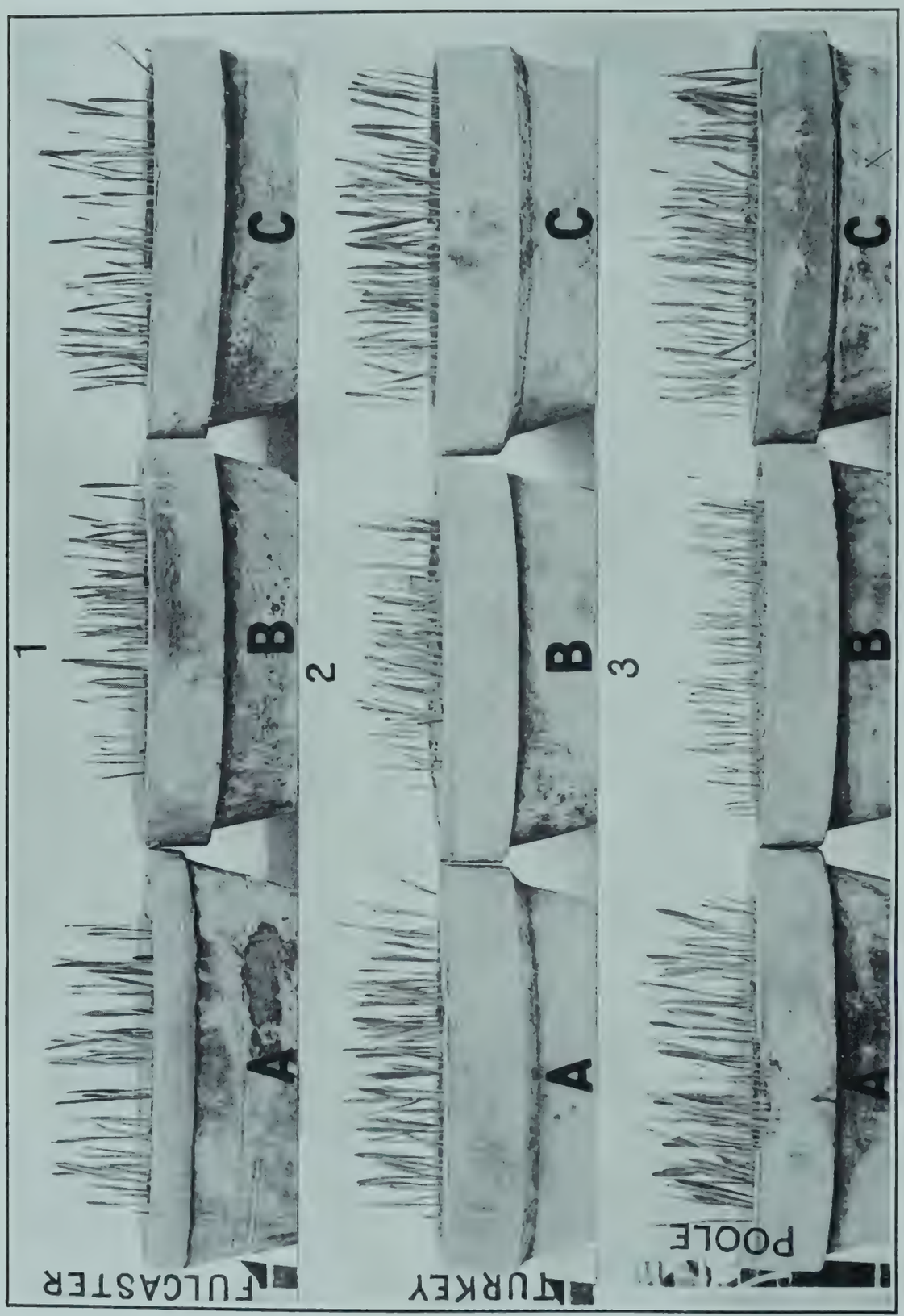

1
A
B
C
FULCASTER
2
A
B
C
TURKEY
3
A
B
C
POOLE

PLATE 72

Stimulating effect of the presoak method of treatment with formalin 1 to 400. (Repetition of experiments shown in Pl. 70, 71):

1. Fulcaster wheat: A, C, seeds presoaked 6 hours, then formalin 1 to 400 for 6 hours, 84 per cent germination, plants stimulated; B, control, 87 per cent germination.

2. Turkey wheat: A, C, seeds presoaked 6 hours, then formalin 1 to 400 for 6 hours, 64 per cent germination; B, control, 67 per cent germination. Note stimulation in presoak-treated plants.

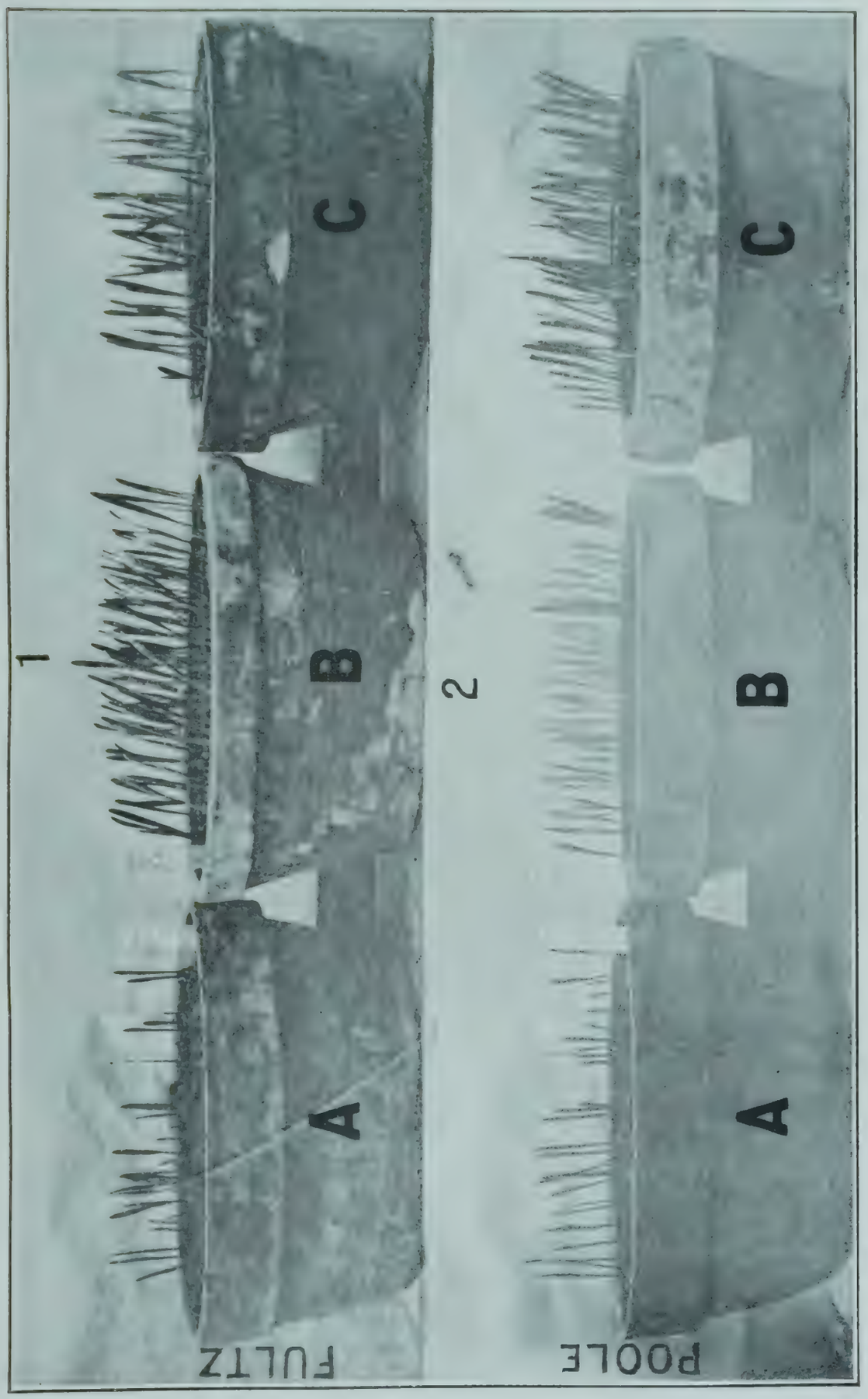
3. Poole wheat: A, C, seeds presoaked 6 hours, then formalin 1 to 400 for 6 hours, 88 per cent germination; B, control, 94 per cent germination. Note increased vigor and stimulation in presoak-treated plants.

PLATE 73

Effect of formalin 1 to 200 treatment for 6 hours, with and without 6-hour presoak:

1. Fultz wheat: A, seeds treated with formalin 1 to 200 for 6 hours without presoak, 43 per cent germination; B, control, 86 per cent germination; C, seeds presoaked 6 hours, then formalin 1 to 200 for 6 hours, 70 per cent germination.

2. Poole wheat: A, seeds treated with formalin 1 to 200 for 6 hours without presoak, 46 per cent germination; B, control, 81 per cent germination; C, seeds presoaked 6 hours, then formalin 1 to 200 for 6 hours, 71 per cent germination. Note stimulation in presoak-treated plants.


1
A
B
C
FULTZ
2
A
B
C
POOLE

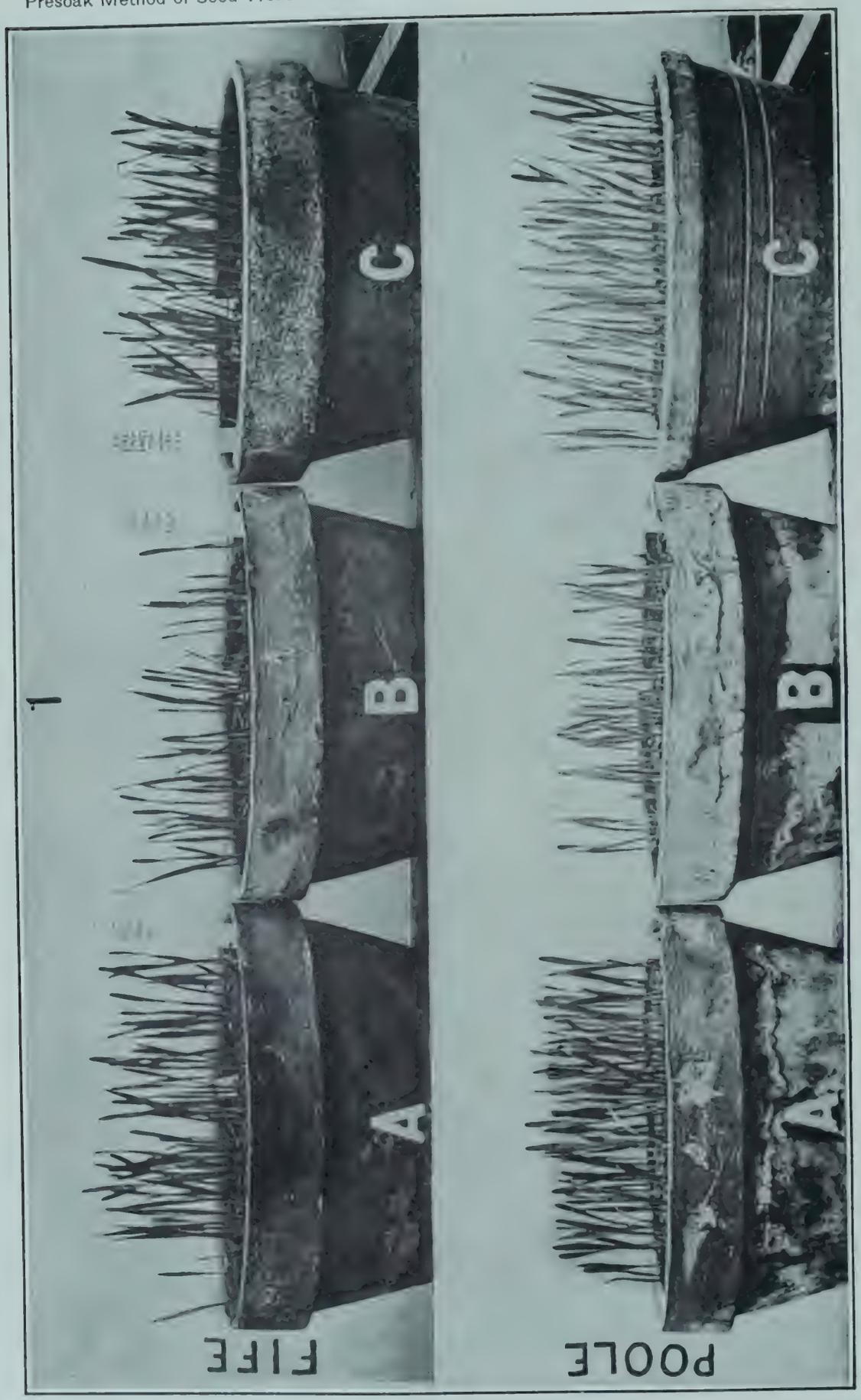

FIFE
A
B
C
POOLE
A
B
C

PLATE 74

Effect of formaiin 1 to 320 treatment for 6 hours, with and without 6-hour presoak:

1. Fife wheat: A, control, 79 per cent germination; B, seeds treated with formalin 1 to 320 for 6 hours, 53 per cent germination; C, seeds presoaked 6 hours, then formalin 1 to 320 for 6 hours, 82 per cent germination.

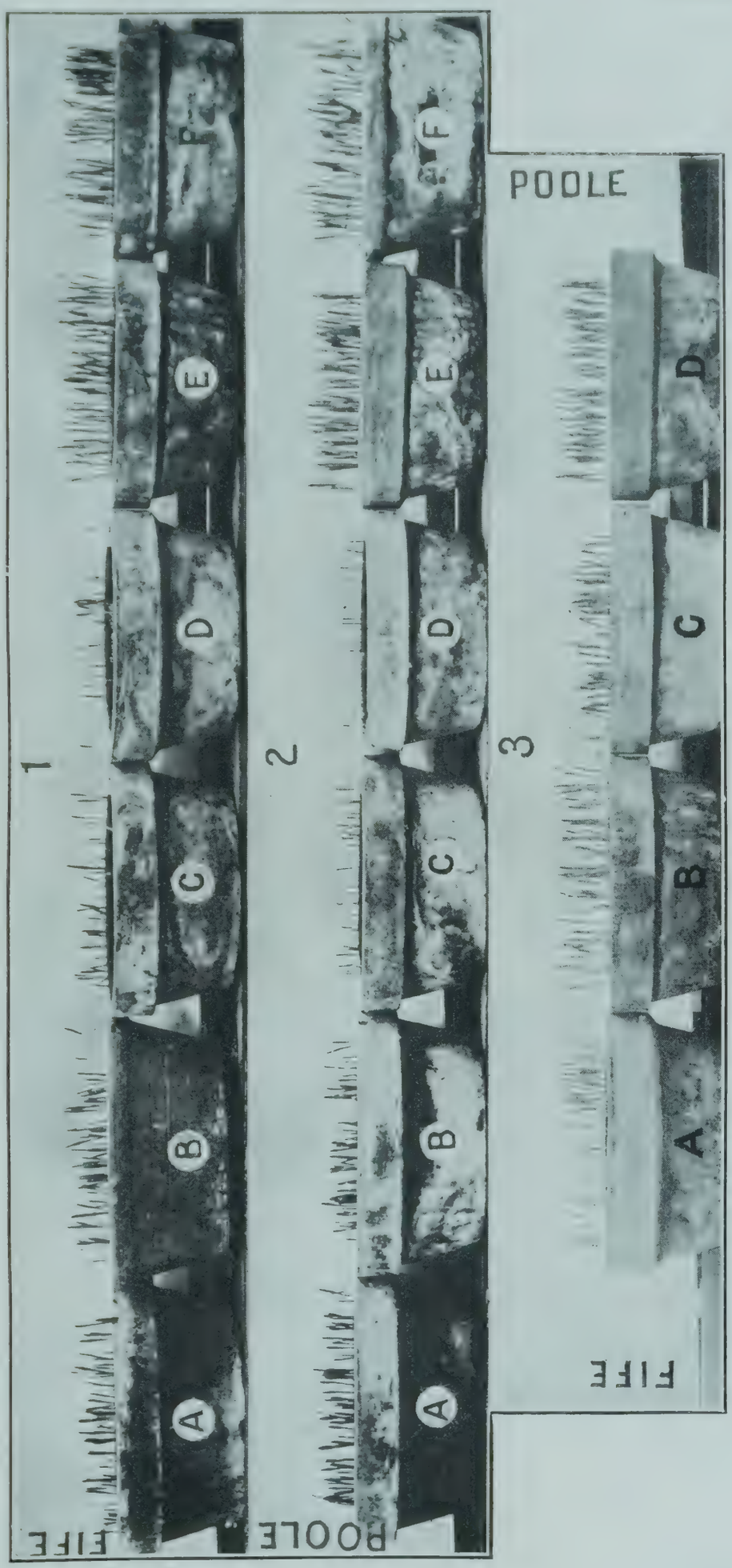
2. Poole wheat: A, control, 88 per cent germination; B, seeds treated with formalin 1 to 320 for 6 hours, 70 per cent germination; C, seeds presoaked 6 hours, then formalin 1 to 320 for 6 hours, 86 per cent germination.

PLATE 75

1. Fife wheat: A, B, control, 83 per cent germination; C, D, seeds treated with formalin 1 to 320 for 3 hours, 62 per cent germination; E, F, seeds presoaked 6 hours, then formalin 1 to 320 for 6 hours, 90 per cent germination.

2. Poole wheat: A, B, control, 85 per cent germination; C, D, seeds treated with formalin 1 to 320 for 6 hours, 55 per cent germination; E, F, seeds presoaked 6 hours, then formalin 1 to 320 for 6 hours, 88 per cent germination.

3. Effect of soaking in water throughout presoak period, compared with procedure of keeping moist 6 hours: A, B, Fife wheat; C, D, Poole wheat; A, C, seeds soaked in water 5 hours, then treated with formalin 1 to 320 for 7 hours; B, D, seeds soaked in water 10 minutes, drained, and kept moist 6 hours, then treated with formalin 1 to 320 for 6 hours. Note the greater stimulation in B and D.


1
2
3
A
B
C
D
E
F
FIFE
POOLE
POOLE
FIFE

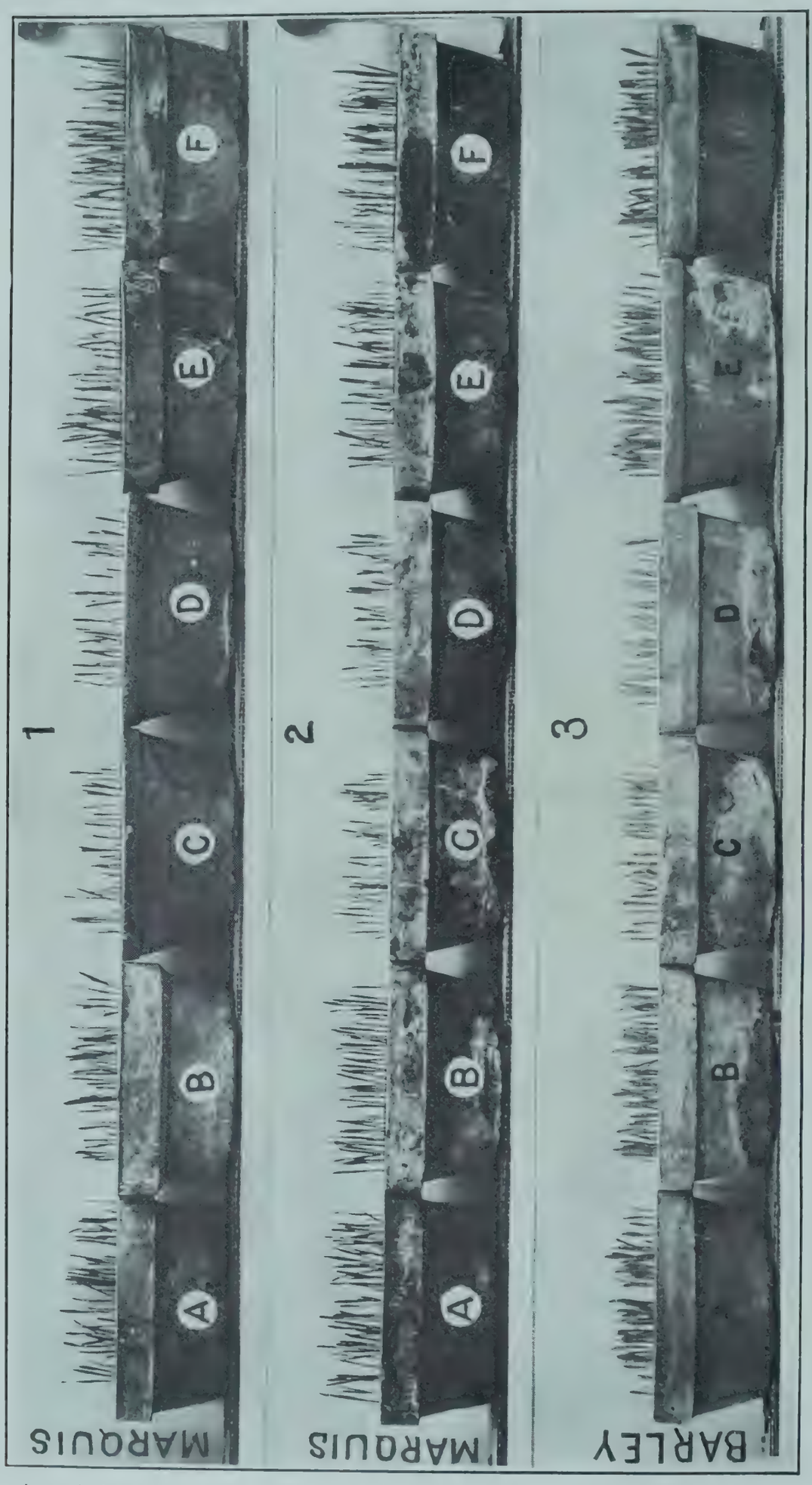

1
MARQUIS
A
B
C
D
E
F
2
MARQUIS
A
B
C
D
E
F
3
BARLEY
B
C
D
E

PLATE 76

Effect of formalin and copper sulphate on wheat and of copper sulphate on barley, with and without presoaking:

1. Marquis wheat: A, B, control, 76 per cent germination; C, D, seeds treated with formalin 1 to 320 for 6 hours, 57 per cent germination; E, F, seeds presoaked 6 hours, then formalin 1 to 320 for 6 hours, 77 per cent germination.

2. Marquis wheat: A, B, control, 84 per cent germination; C, D, seeds treated with copper sulphate 1 to 80 for ½ hour, and limed, 65 per cent germination; E, F, seeds presoaked 6 hours, then copper sulphate 1 to 80 for ½ hour, and limed, 79 per cent germination.

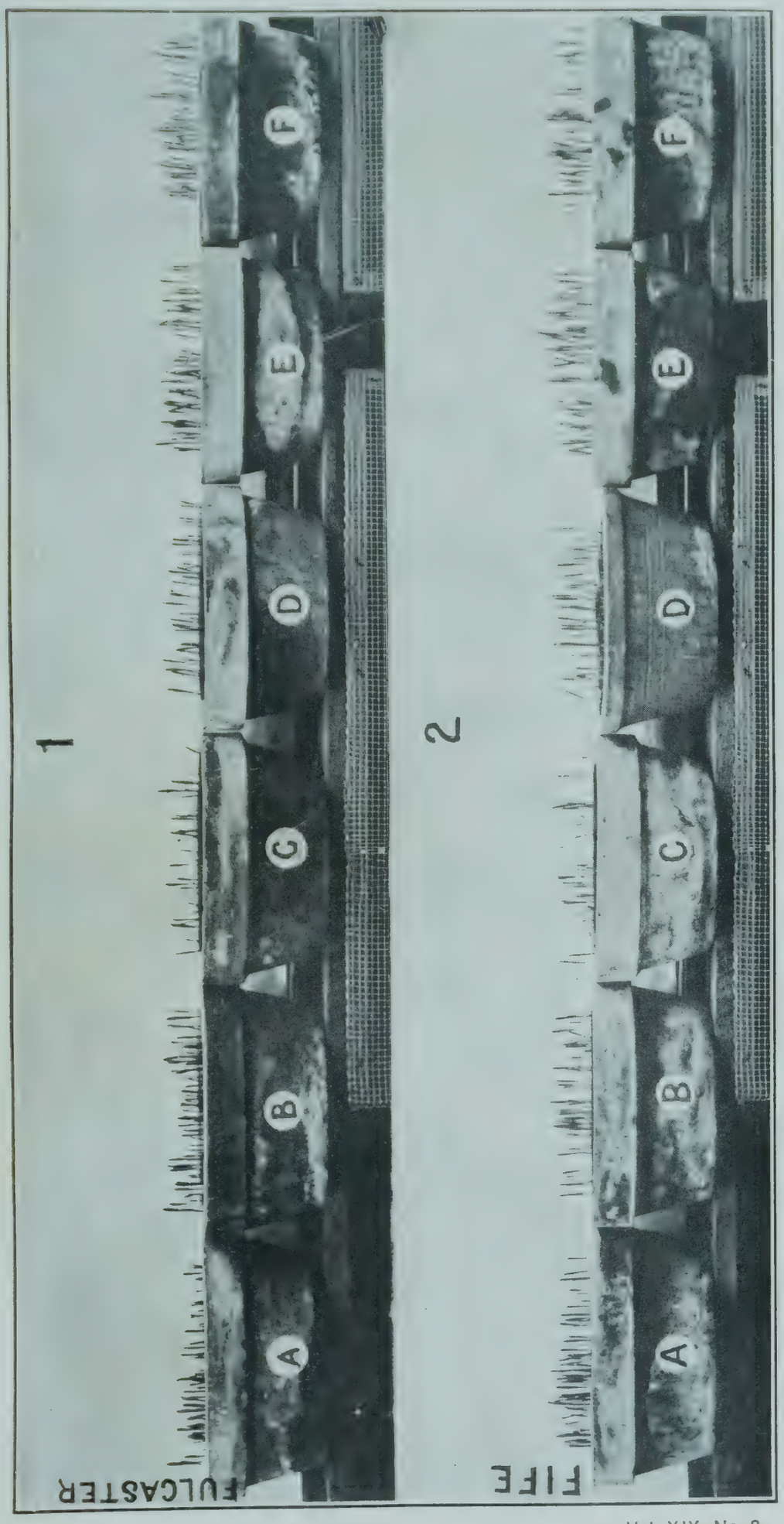
3. Tennessee winter barley: A, B, control, 89 per cent germination; C, D, seeds treated with copper sulphate 1 to 80 for ½ hour, and limed, 72 per cent germination; E, F, seeds presoaked 6 hours, then copper sulphate 1 to 80 for ½ hour, and limed, 83 per cent germination.

PLATE 77

Effect of presoak method used with copper-sulphate treatment of wheat:

1. Fulcaster wheat: A, B, control, 81 per cent germination; C, D, seeds treated with copper sulphate 1 to 80 for ½ hour, and limed, 57 per cent germination; E, F, seeds presoaked 8 hours, then copper sulphate 1 to 80 for ½ hour, and limed, 82 per cent germination.

2. Fife wheat: A, B, control, 79 per cent germination; C, D, seeds treated with copper sulphate 1 to 80 for ½ hour, and limed, 52 per cent germination; E, F, seeds presoaked 8 hours, then copper sulphate 1 to 80 for ½ hour, and limed, 81 per cent germination.


1
FULCASTER
A
B
C
D
E
F
2
FIFE
A
B
C
D
E
F

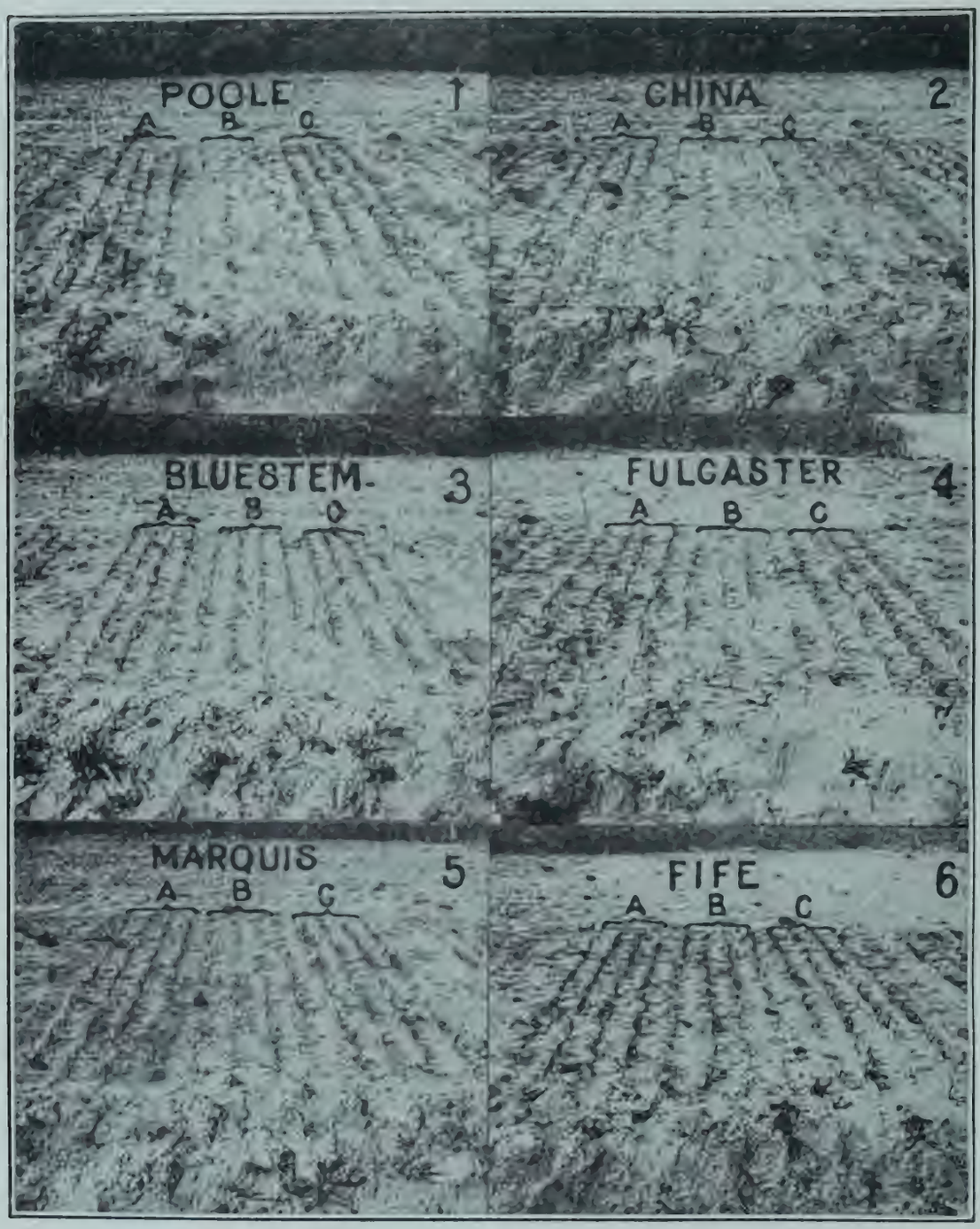

POOLE 1
A B C
CHINA 2
A B C
BLUESTEM 3
A B C
FULCASTER 4
A B C
MARQUIS 5
A B C
FIFE 6
A B C

PLATE 78

Effect of presoak method used with formalin 1 to 320 on wheat under field conditions: 1. Poole; 2. China; 3. Bluestem; 4. Fulcaster; 5. Marquis; 6. Fife.

A.—Eight hundred seeds in four rows, soaked in water 10 minutes, kept moist 6 hours, soaked in formalin 10 minutes, kept moist 6 hours, dried overnight.

B.—Eight hundred seeds in four rows, soaked in formalin 1 to 320 for 10 minutes, kept moist 6 hours, dried overnight.

C.—Eight hundred seeds in four rows, control.

PLATE 79

Effect of presoak method used with formalin 1 to 400 on blackchaff bacteria:

A.—Controls, dry-heat sterilized wheat seeds inoculated with blackchaff isolation No. 377 from South Dakota, dried, and planted on agar without further treatment.

B.—Sterilized wheat seeds inoculated with isolation No. 377, dried overnight, then soaked in sterile tap water 10 minutes and kept moist 6 hours, then soaked in formalin 1 to 400 for 10 minutes and kept moist 6 hours, dried, and planted.

Note bacterial growth around untreated seeds and absence of growth in presoaked formalin-treated seeds. Two Petri dishes photographed out of a set of 120 dishes in experiment III on tenth day.

A
B

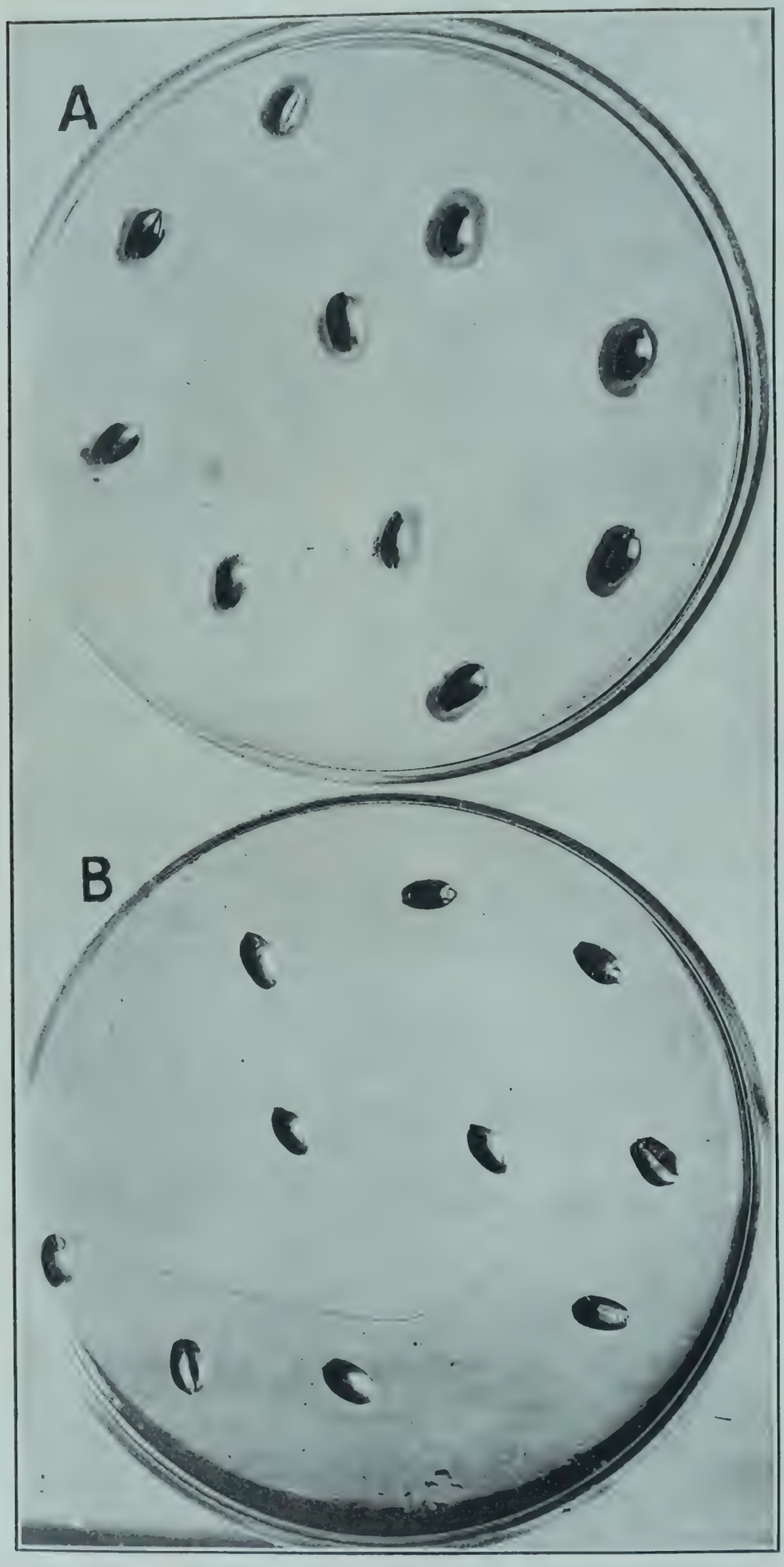

A
B

PLATE 80

Effect of presoak method used with formalin 1 to 400 on blackchaff bacteria:

A.—Controls, dry-heat sterilized wheat seeds inoculated with blackchaff isolation No. 373 from North Dakota, dried, and planted on agar without further treatment.

B.—Sterilized wheat seeds inoculated with isolation No. 373, dried overnight, then soaked in sterile tap water 10 minutes, kept moist 6 hours, then soaked in formalin 1 to 400 for 10 minutes, drained, kept moist 6 hours, dried, and planted.

Note bacterial growth around untreated seeds and absence of growth in presoaked formalin-treated seeds. Two Petri dishes photographed out of a set of 120 dishes in experiment III on tenth day.

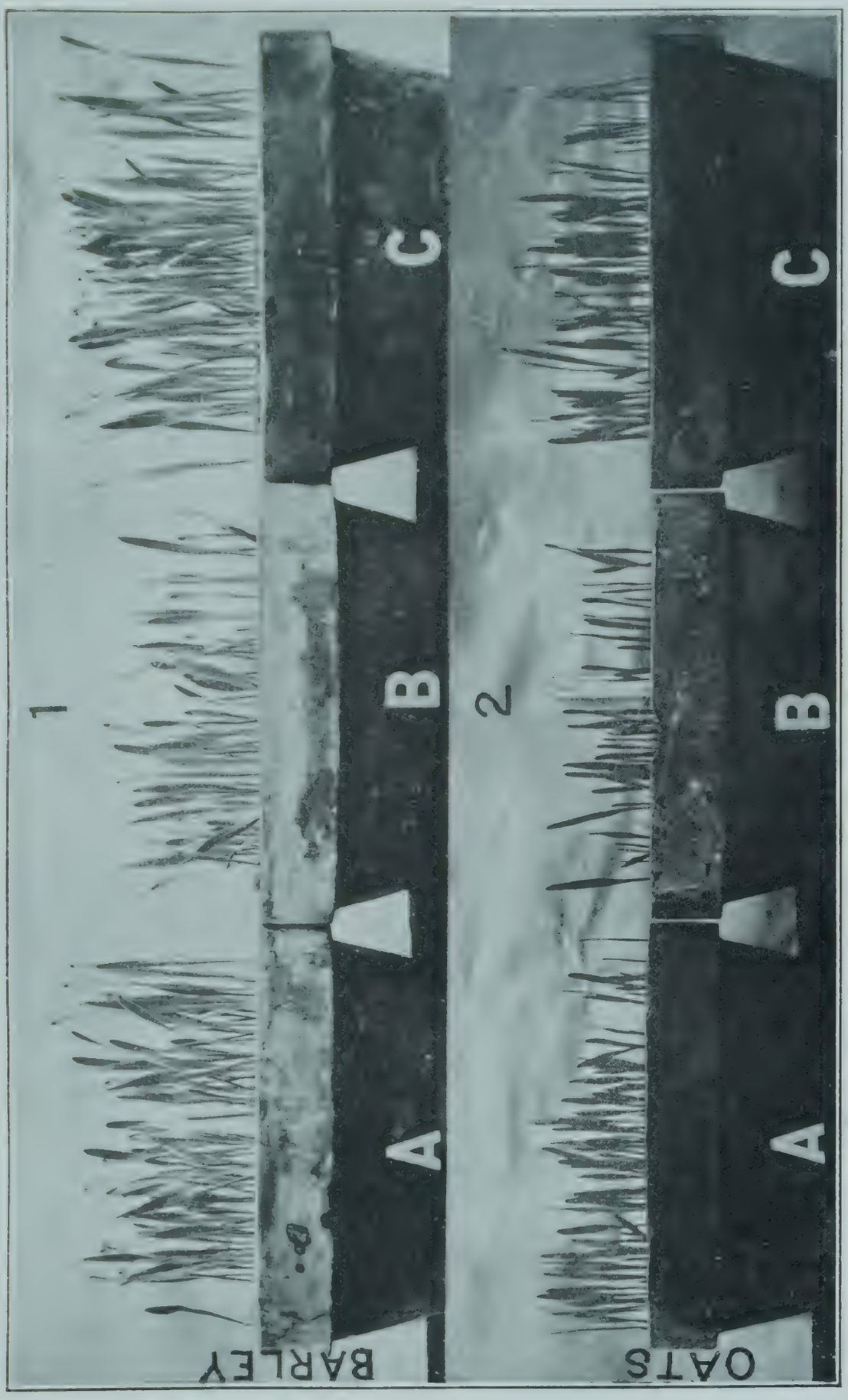
177286°—20——6

PLATE 81

Effect of presoak method on barley and oats:

1. Chevalier barley: A, control, 92 per cent germination; B, seeds treated with formalin 1 to 320 for 6 hours, 58 per cent germination; C, seeds presoaked 6 hours, then formalin 1 to 320 for 6 hours, 91 per cent germination.

2. Burt oats: A, control, 94 per cent germination; B, seeds treated with formalin 1 to 320 for 6 hours, 66 per cent germination; C, seeds presoaked 6 hours, then treated with formalin 1 to 320 for 6 hours, 94 per cent germination.


1
2
A
B
C
A
B
C
BARLEY
OATS

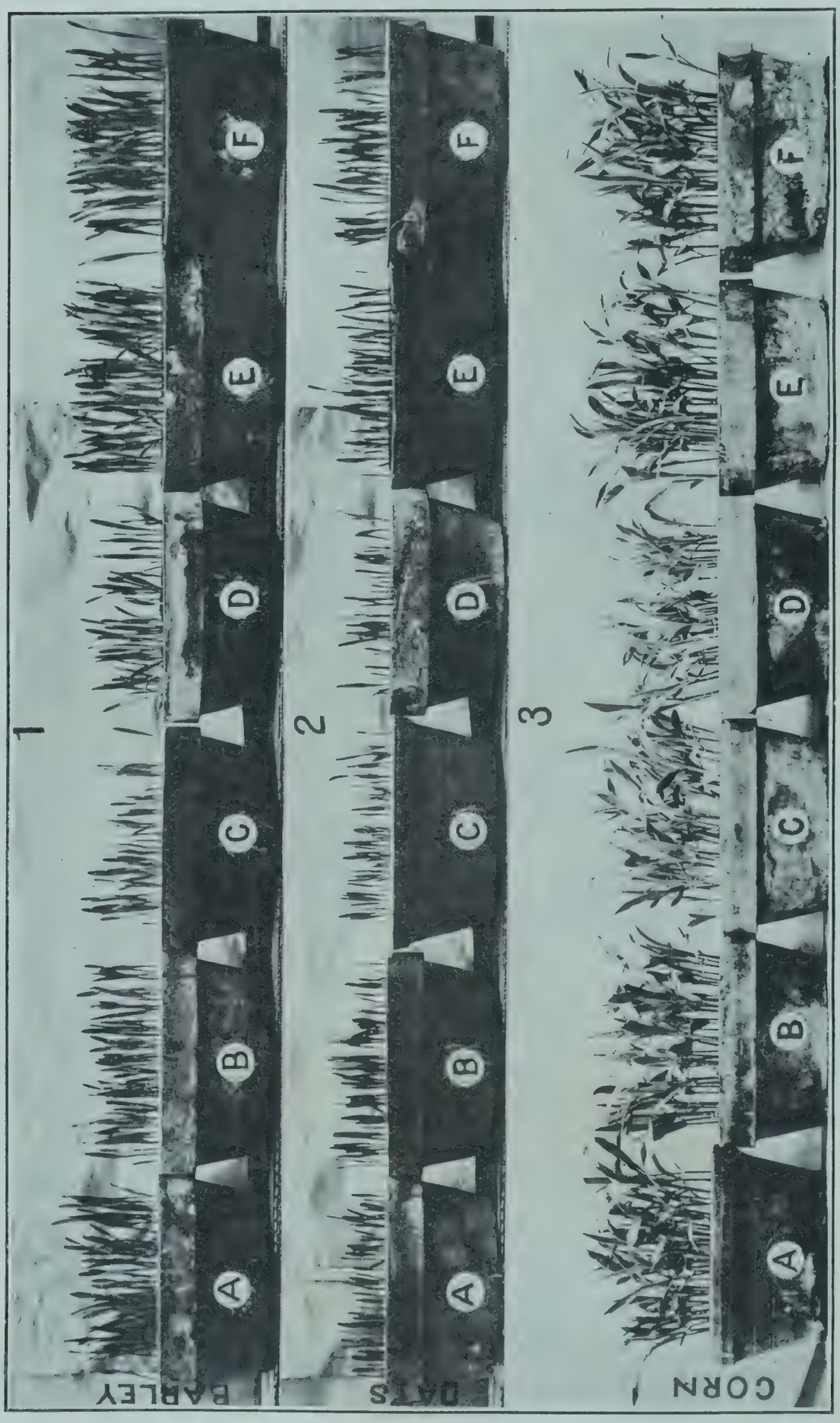

1
2
3
A
B
C
D
E
F
BARLEY
OATS
CORN

PLATE 82

Effect of presoak method used on barley, oats, and corn:

1. Chevalier barley: A, B, control, 92 per cent germination; C, D, seeds treated with formalin 1 to 320 for 10 minutes, then kept moist (covered) 6 hours, 62 per cent germination; E, F, seeds presoaked 6 hours, then formalin 1 to 320 for 6 hours, 92 per cent germination. Photographed on seventh day.

2. Burt oats: A, B, control, 96 per cent germination; C, D, seeds treated with formalin 1 to 320 for 6 hours, 71 per cent germination; E, F, seeds presoaked 6 hours, then formalin 1 to 320 for 6 hours, 92 per cent germination. Photographed on seventh day.

3. Bantam Evergreen corn: A, B, control, 94 per cent germination; C, D, seeds treated with formalin 1 to 200 for 4 hours, 90 per cent germination; E, F, seeds actually soaked in water 10 hours, then treated with formalin 1 to 200 for 4 hours, 92 per cent germination. Count taken on twelfth day, photographed on sixteenth day. The presoaked seeds are stimulated.

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VOL. XIX WASHINGTON, D. C., AUGUST 2, 1920 NO. 9

DAILY DEVELOPMENT OF KERNELS OF HANNCHEN BARLEY FROM FLOWERING TO MATURITY AT ABERDEEN, IDAHO[1]

By HARRY V. HARLAN

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INTRODUCTION

Several years ago the author made a few elementary experiments on the function of the awn in barley. In these studies the awns were clipped from some spikes and not from others. The effect on the development of the kernels was so striking that in 1915 a more elaborate experiment was carried out by the author and Stephen Anthony. The development of kernels on normal and clipped spikes was determined from flowering to maturity. The method of study proved so satisfactory that it led to other investigations in which it offered the same possibility of application. The development of barley on dry land and on irrigated land, the response to irrigation water, and the differences in varietal behavior have all been studied by this means. The last study has been undertaken since the resignation of Mr. Anthony. In these studies, kernel growth has been used as an index of effect. Yield and size of mature kernels, while probably a safe summary of the effects of variations of treatment or differences of types, do not throw much light on the time when the effect occurred, or always on the reasons therefor. This group of studies has been carried on with the idea that variations from a basic growth curve showing the inception, duration, and degree of response would be much more illuminating than the single observation of the final result.

A number of studies have been completed, and it is the intention to publish the results of the special projects from time to time. The results represent a normal growth curve. It is intended that this curve shall form the basis of comparison in the later studies and that it shall

[1] These studies were made on the Aberdeen Substation, Aberdeen, Idaho, in connection with cereal experiments conducted cooperatively by the Idaho Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture.

be a connecting link between the various studies. In this paper the results with the Hannchen variety are given in full for one year at Aberdeen, Idaho. The Hannchen variety was chosen for this basic statement because it has been used more extensively than any other variety. The growth at Aberdeen is selected both because of the fact that most of the studies made and projected are located there and because of the remarkable uniformity of growth of plants at that place from season to season. In three different years the period from flowering to maturity has extended over exactly 26 days. This uniformity, coupled with accurate sampling, has made it possible to take samples at intervals as short as 24 hours or even less and still show consistent growth. In no previous studies on cereal crops, either here or abroad, have samples been taken more frequently than at 3-day intervals, yet it is readily seen in figure 1 that most of the growth in length is completed in a period of three days. The measurements of kernel dimensions are an important index of development which seems to have been generally ignored.

HISTORICAL REVIEW

The published data on kernel development have little relation to the various lines of investigation at Aberdeen, Idaho. Differences of location and variety make anything but general comparisons difficult in this connection.

The studies of kernel development previously reported in the cereals have been the outcome of a wide range of experiments and are too numerous to be reviewed in detail. Kudelka (*4*),[2] Lermer and Holzner (*5*), and many others have published on the origin and development of tissues in the caryopsis as a whole, or even in the entire plant. Some investigations have been specifically devoted to tissues of the pericarp. Johannsen (*3*), Brenchley (*1*), Schjerning (*6*, *7*), and numerous others have investigated the chemical changes of growth and maturation. The work of these investigators is referred to later. Their experiments were carried on under relatively unfavorable conditions. The contrast is remarkable between the humid climates of Denmark and England, with their frequent storms and days of low activity, and the arid climate of Aberdeen. Schjerning had a difference of 12 days in the maturity of his plots in two succeeding years.

The detail of the experiment at Aberdeen is more nearly like those of Brenchley (*1*), Schjerning (*6*, *7*), and Johannsen (*3*) than those of the other investigators. It differs from these in a reduction of the period between samples and in the extensive study of the physical indices of length and diameter of kernel. The chemical and morphological phases are not comparable with those of Schjerning and Johannsen.

[2] Reference is made by number (italic) to "Literature cited," p. 429.

EXPERIMENTAL METHODS

Such success as has been obtained in reducing the interval of sampling is due in large part to the accuracy of tagging spikes at the same stage of development. This, in turn, rests on an observation made several years

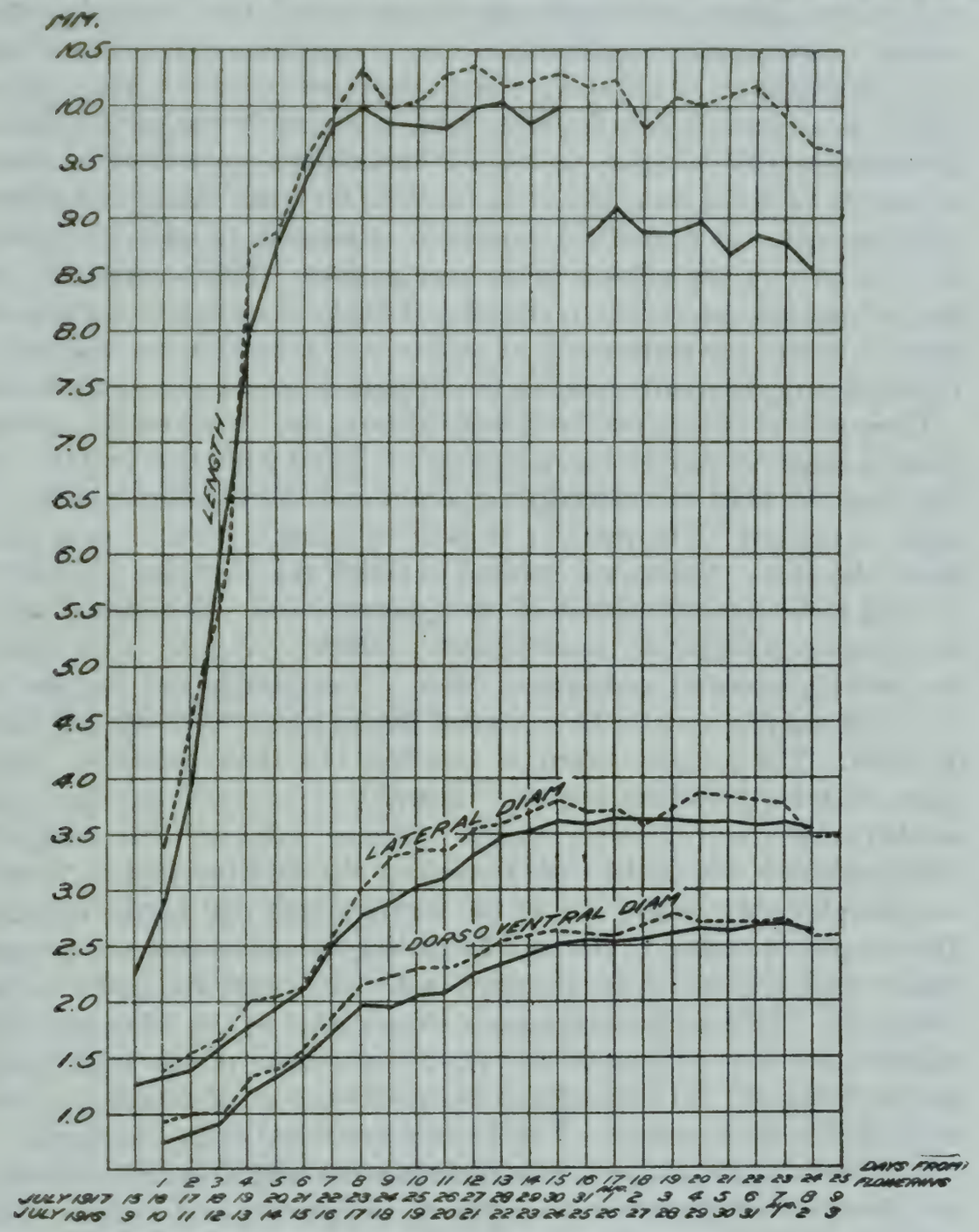

FIG. 1.—Graph showing length, lateral diameter, and dorsoventral diameter of barley kernels for the 25 days following flowering. The broken lines give the data for 1916, the solid lines the data for 1917.

before the work was started. In agronomic notes taken upon cereal varieties, the time of heading and the time of ripening have always been considered to be important statements of development. Of these, the time of heading is thought to be especially valuable, because drouth and other climatic factors that greatly influence maturity have usually affected the plant but little up to this stage.

While time of heading in barley is doubtless significant, it is very difficult to determine. A barley spike may be visible two or three days before it is fully exserted from the sheath. In some varieties the spikes are never completely exserted. In a study of this difficulty it was noticed that the emergence of the awns offered opportunity for a tangible observation. Upon trial it was found to be a very accurate index of the stage of the development of the spike. With the observation as a basis, spikes tagged as uniform before flowering were of so nearly the same stage of development that, despite individual fluctuations, growth in as short periods as 12 hours was evident in the data for many days; and almost until maturity the individual variations in samples of only two spikes did not obscure the growth in 24-hour periods. The accuracy of the method and the spectacular uniformity of Idaho seasons is well shown in figure 2, where the percentages of moisture in kernels in the seasons of 1916 and 1917 essentially coincide throughout the entire period of growth.

Three or four days after the tips of the awns are visible on the earliest culms a large number of culms are to be found with tips visible. At this time the plots are carefully inspected and the requisite number of culms is marked. The marking is done by tying a piece of wool yarn about the culm. Culms are selected in which the awns are protruding ¼ to ½ inch above the sheath of the uppermost leaf. A sufficient number of culms is tagged to insure against accident. As soon as the spikes are partially exserted a sample is taken. This sample and the one on the following day usually have several florets which have not yet been fertilized. The samples taken in the first few days consist of three spikes in order to secure a greater quantity of material, but later the number is reduced to two per sample. In most cases only one sample is taken each day, but in the cases furnishing the data reported in Table I two samples were taken, one in the morning and one in the evening. The samples are taken in the field by cutting the culms near the ground. These culms and spikes are wrapped in a moist towel and taken to the laboratory. As a protection against evaporation in the laboratory the spikelets are removed one at a time, the remainder of the spike being left in the towel. To secure the data rapidly and satisfactorily two men work on the same sample. The kernels are taken from the florets by the operator of the calipers, who measures the length, lateral diameter, and dorsoventral diameter in tenths of millimeters and records these measurements. The kernels are then passed to the operator of the balance and weighed to tenths of milligrams. Only the kernels on a single side of each spike are measured and weighed individually. The kernels of the other side of the spike are added to those measured individually and weighed to obtain a larger sample. These are placed in small vials and dried in a water-jacket oven. The vials are then corked, and the material is preserved for later analysis.

EXPERIMENTAL MATERIAL

Most of the data presented herein were obtained in 1917, but many of the graphs contain curves of the data for 1916 as well. The curves for 1916 are added merely for comparison and to give an idea of the

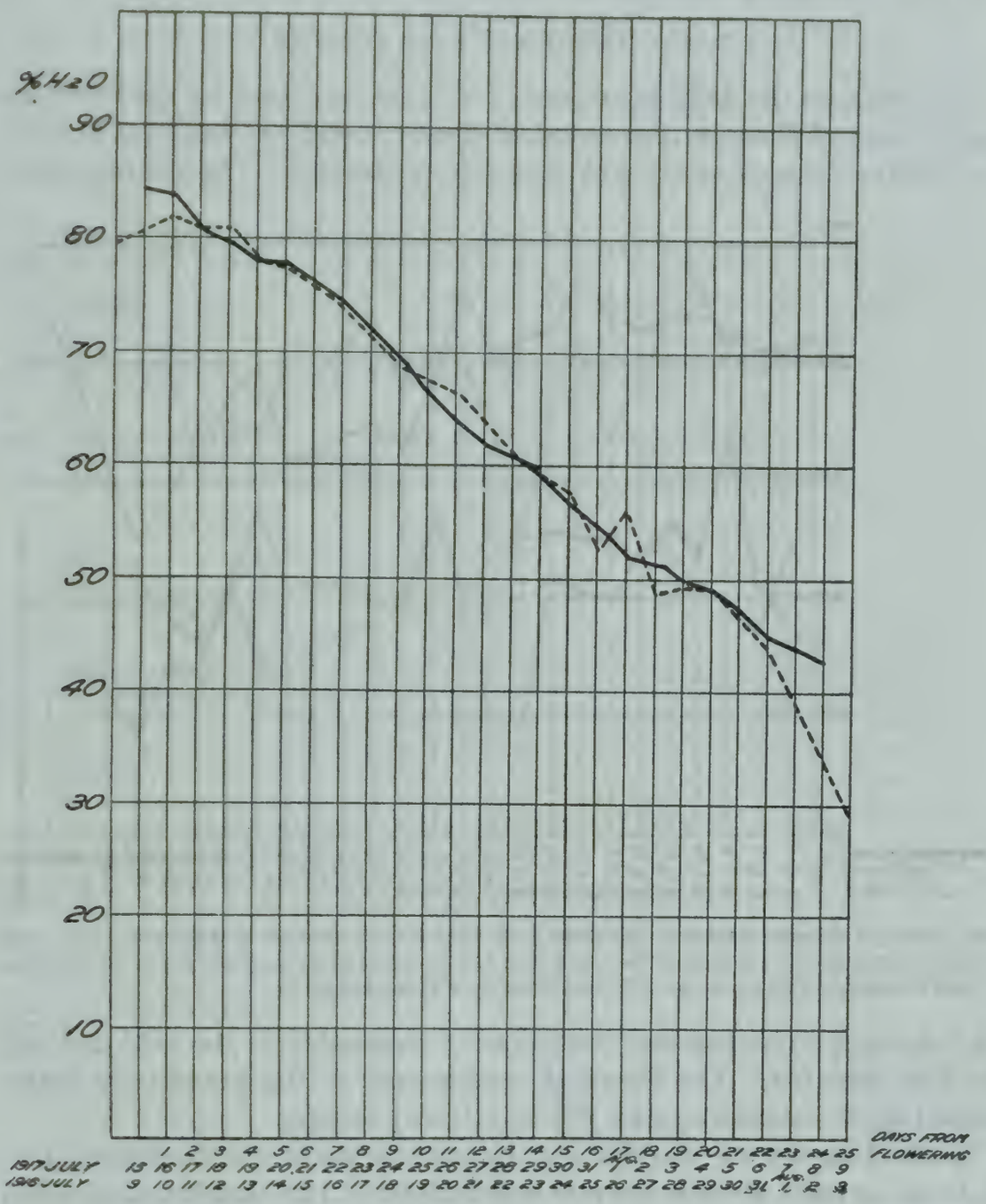

FIG. 2.—Graph showing percentage of moisture per kernel from date of flowering. The broken line gives the data for 1916, the solid line the data for 1917.

range of annual fluctuations. The larger growth in 1916 was due, doubtless, to the more generous application of water in that year. The plots were in flower a week earlier in 1916 than in 1917 and may have had some advantage of season. In figure 3 the maximum and mean temperatures for the two years are shown. These are of interest later in their relation to daily fluctuation. In both years the barley was

grown under irrigation and was watered sufficiently often to insure a satisfactory growth. In 1916, only one sample was taken per day, and no samples were taken on Sunday. In 1917, samples were taken morning and evening, on Sundays as well as on week days; and the series is thus more nearly complete than in the previous year.

DAILY INCREMENT OF VOLUME

The data on the daily increment of volume, as shown by the increased length, lateral diameter, dorsoventral diameter, and wet weight of kernels, fall into two classes, which will be treated separately. The measurements

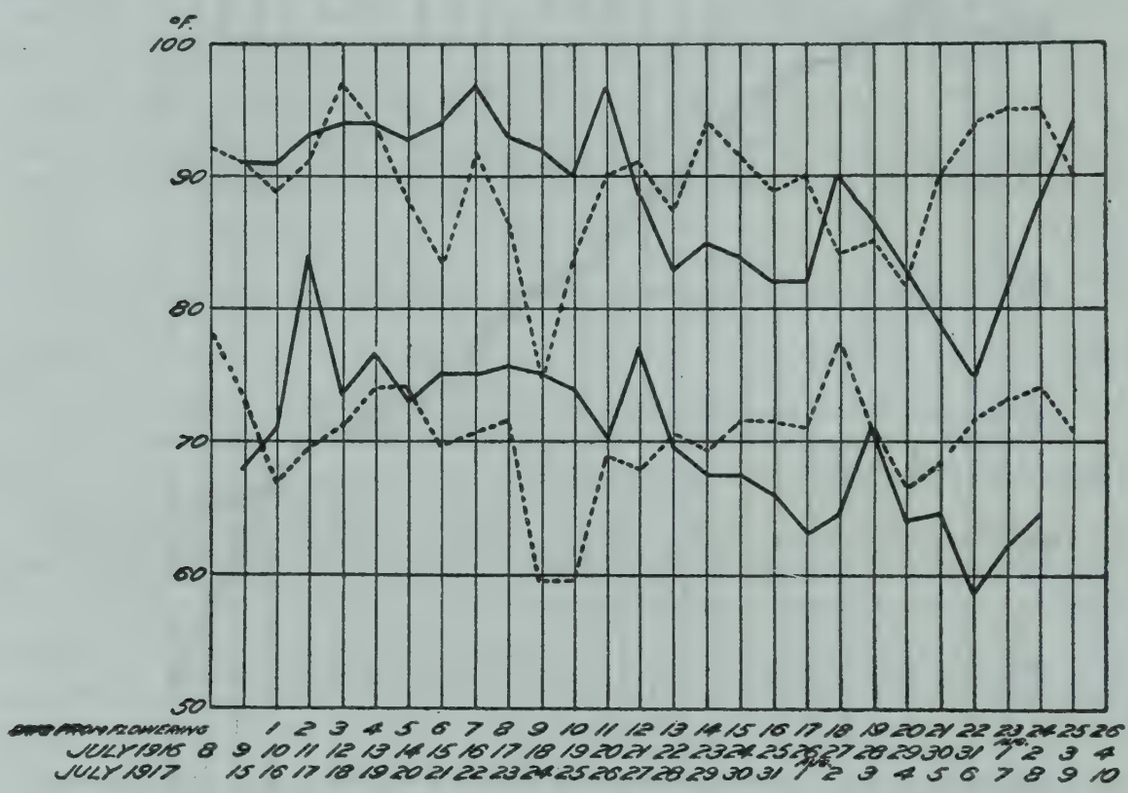

FIG. 3.—Graph showing maximum and mean daily temperatures recorded at Aberdeen, Idaho, from July 8 to August 4, 1916 (broken line), and from July 15 to August 10, 1918 (solid line). In both years these temperatures are for 26 days following flowering of Hannchen barley.

of volume are observations immediately obtainable in the field and will be first reported. The chemical constituents of the kernels are determined in the laboratory and will be referred to later.

Table I shows the weights and measurements of the individual kernels on one side of each spike in the samples. The samples were taken at approximately 6 a. m. and 7 p. m. These hours marked the beginning and the end of effective sunshine. The morning samples on each date are on the left half of the table and evening samples on the right half. The florets are numbered from the base of the spike toward the tip, so that the figures in each column represent a spike with the base toward the top of the page. In the earlier samples where three spikes were taken, the record of one spike has been omitted from this table because of lack of space. While the number of data makes it difficult

to visualize the changes that take place from day to day, the nature of the individual spikes can be seen only in this table. The averages do not give a correct indication of the condition of a single spike. The variations between kernels are reduced by averages, and the difficulty of securing such averages is not apparent in the absence of the complete data. It is readily seen in the table that in instances where the spike is short it is often a question which kernel should be considered the third or the fourth. Such decisions affect the averages, and they must be made by some arbitrary method, since the actual number of sterile nodes at the base can not be used successfully as a basis. The curve of the kernels of a single spike usually is better than the average of two spikes unless the two spikes have the same number of kernels. The extremes of the curves are especially liable to distortion in averages. Of course, the curve of the growth by days is much improved by the use of averages. The same process that reduces the fluctuation in the record of a spike increases the gap between samples.

TABLE I.—*Normal growth of Hannchen barley in 12-hour periods from flowering to maturity, at Aberdeen, Idaho, in 1917*

JULY 15

Kernel No. from base of spike.	6 a. m.								7 p. m.							
	Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—		Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
	Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	.....	.....	.....	.....	.....	.....	.....	.....	[a]S	S	S	S	S	S	S	S
2	.....	.....	.....	.....	.....	.....	.....	.....	[b]0.0005	[b]0.0007	1.9	1.9	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....	[b].0012	.0013	1.9	2.0	.....	.....	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	.....	.0014	.0015	2.1	2.2	1.2	1.2	.....	.....
5	.....	.....	.....	.....	.....	.....	.....	.....	.0018	.0020	2.1	2.4	1.2	1.2	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.0020	.0020	2.2	2.3	1.3	1.2	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.0022	.0025	2.5	2.7	1.3	1.3	.....	.....
8	.....	.....	.....	.....	.....	.....	.....	.....	.0025	.0026	2.5	2.8	1.4	1.3	.....	.....
9	.....	.....	.....	.....	.....	.....	.....	.....	.0027	.0026	2.7	2.6	1.4	1.3	.....	.....
10	.....	.....	.....	.....	.....	.....	.....	.....	.0026	.0027	2.5	2.7	1.3	1.2	.....	.....
11	.....	.....	.....	.....	.....	.....	.....	.....	.0023	.0025	2.3	2.6	1.3	1.3	.....	.....
12	.....	.....	.....	.....	.....	.....	.....	.....	.0019	.0019	2.2	2.3	1.2	1.3	.....	.....
13	.....	.....	.....	.....	.....	.....	.....	.....	.0014	.0014	2.1	2.3	1.2	1.1	.....	.....
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	[b].0005	.....	1.0	.....	.....	.....	.....

JULY 16

1	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
2	[b]0.0011	[b]0.0005	2.0	1.6	.....	.....	.....	.....	S	S	S	S	S	S	S	S
3	.0022	.0014	2.6	2.0	1.3	1.2	.....	.....	0.0009	0.0007	1.9	1.6	1.3	0.8	0.6	0.5
4	.0019	.0020	2.4	2.4	1.3	1.2	.....	0.7	.0028	.0012	3.1	1.8	1.4	1.1	.8	.6
5	.0020	.0025	2.3	2.5	1.3	1.3	.....	.8	.0031	.0018	3.0	2.2	1.4	1.2	.8	.7
6	.0023	.0032	2.4	3.0	1.3	1.4	.....	.8	.0033	.0025	3.4	2.5	1.3	1.3	.8	.7
7	.0024	.0032	2.5	3.2	1.3	1.4	0.7	.8	.0042	.0029	3.7	3.0	1.4	1.4	.8	.8
8	.0028	.0033	2.7	3.2	1.3	1.3	.8	.8	.0041	.0028	3.7	3.0	1.4	1.4	.8	.7
9	.0030	.0035	3.2	3.3	1.4	1.4	.8	.8	.0045	.0030	4.0	3.1	1.4	1.4	.8	.8
10	.0029	.0039	2.7	3.6	1.3	1.4	.8	.8	.0043	.0030	4.0	3.0	1.3	1.4	.8	.8
11	.0027	.0036	2.9	3.2	1.3	1.5	.7	.8	.0039	.0023	4.0	2.4	1.4	1.2	.8	.7
12	.0023	.0029	2.6	3.1	1.4	1.3	.7	.7	.0029	S	3.4	S	1.3	S	.7	S
13	.0017	.0018	2.3	1.9	1.1	1.3	.5	.7	.....	.....	.....	.....	.....	.....	.....	.....

[a] The letter S indicates a sterile spikelet. [b] Unfertilized.

TABLE I.—*Normal growth of Hannchen barley in 12-hour periods from flowering to maturity, at Aberdeen, Idaho, in 1917*—Continued

JULY 17

Kernel No. from base of spike.	6 a. m.								7 p. m.							
	Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—		Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kerne on spike—	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
	Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	.....	0.0012	.....	2.1	.....	1.0	.....	0.6	0.0029	0.0033	2.8	3.5	1.4	1.4	0.8	0.8
3	0.0022	.0023	2.4	2.6	1.2	1.3	0.7	.7	.0045	.0051	3.6	3.9	1.3	1.4	.8	.8
4	.0025	.0030	2.7	3.2	1.2	1.3	.7	.8	.0055	.0052	4.4	4.2	1.4	1.5	.9	.9
5	.0033	.0034	2.9	3.3	1.3	1.4	.8	.8	.0058	.0056	4.6	4.8	1.6	1.5	.9	.9
6	.0033	.0037	3.0	3.5	1.4	1.4	.8	.8	.0061	.0064	4.9	5.0	1.3	1.4	.9	.9
7	.0038	.0039	3.1	3.7	1.5	1.4	.9	.8	.0069	.0071	5.0	5.5	1.4	1.4	.9	.9
8	.0036	.0043	3.5	3.8	1.5	1.4	.9	.9	.0076	.0067	5.6	5.5	1.4	1.5	.9	.9
9	.0038	.0048	3.2	4.3	1.4	1.5	.9	.9	.0062	.0068	4.7	5.6	1.6	1.5	.8	.9
10	.0038	.0043	3.4	4.1	1.5	1.3	.9	.8	.0071	.0069	5.7	5.5	1.5	1.5	.9	.9
11	.0029	.0036	3.1	3.7	1.3	1.3	.8	.8	.0067	.0062	5.4	5.1	1.4	1.5	.9	.8
12	.0031	.0029	3.0	3.4	1.4	1.3	.8	.7	.0057	.0050	4.8	4.7	1.4	1.4	.8	.8
13	.0025	.....	2.8	.....	1.3	.....	.8	.....	.....	.0028	.....	2.9	.....	1.3	.....	.7
14	.0018	.....	2.1	.....	1.3	.....	.6	.....	.....	.....	.....	.....	.....	.....	.....	.....

JULY 18

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0046	0.0035	3.8	3.6	1.5	1.3	0.9	0.8	0.0048	0.0054	4.0	4.5	1.5	1.5	0.7	0.8
3	.0076	.0047	5.2	4.0	1.6	1.4	.9	.9	.0073	.0075	5.6	5.6	1.5	1.6	.8	.9
4	.0088	.0056	6.3	4.6	1.6	1.4	.9	.9	.0079	.0086	5.9	6.1	1.6	1.6	.8	.9
5	.0094	.0060	6.4	4.7	1.6	1.4	.9	.9	.0083	.0089	6.3	6.9	1.6	1.7	.9	.9
6	.0095	.0067	6.8	5.4	1.5	1.6	.9	.9	.0082	.0095	6.2	6.7	1.6	1.6	.9	1.0
7	.0100	.0075	6.9	5.9	1.6	1.5	.9	.9	.0098	.0096	7.0	6.8	1.6	1.7	1.0	1.0
8	.0097	.0079	7.1	6.1	1.6	1.6	1.0	.9	.0102	.0108	7.0	7.5	1.7	1.6	1.0	1.1
9	.0093	.0076	6.8	5.9	1.6	1.5	.9	.9	.0104	.0092	7.4	6.9	1.7	1.7	1.0	1.0
10	.0089	.0074	6.8	5.9	1.6	1.5	.9	.8	.0096	.0090	7.3	6.6	1.6	1.6	1.0	.9
11	.0089	.0073	6.5	5.9	1.5	1.5	.8	.8	.0083	.0086	6.7	6.5	1.6	1.6	.9	.9
12	.0068	.0064	6.0	5.5	1.5	1.5	.8	.8	.0075	.0068	6.3	5.7	1.6	1.6	.8	.8

JULY 19

1	0.0023	.....	2.8	.....	1.3	.....	0.7	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	.0070	0.0050	5.5	4.8	.5	1.5	.8	0.8	0.0100	0.0084	7.0	6.2	1.7	1.7	1.0	0.9
3	.0091	.0090	6.4	6.6	1.7	1.6	.9	.9	.0125	.0109	8.0	7.3	1.8	1.7	1.2	1.0
4	.0100	.0108	6.7	7.7	1.7	1.7	1.0	1.1	.0142	.0122	8.7	8.1	1.8	1.8	1.2	1.0
5	.0114	.0128	7.9	8.3	1.7	1.7	1.1	1.2	.0151	.0131	9.0	8.3	1.9	1.7	1.2	1.2
6	.0123	.0132	8.3	8.2	1.8	1.8	1.1	1.3	.0160	.0136	9.1	8.4	1.9	1.8	1.3	1.3
7	.0128	.....	8.0	.....	1.8	.....	1.2	.....	.0170	.0149	9.3	8.8	2.0	1.9	1.3	1.3
8	.0129	.0151	8.3	8.5	1.8	1.8	1.1	1.3	.0166	.0146	9.3	8.7	1.9	1.9	1.4	1.3
9	.0127	.0156	8.0	8.6	1.8	2.0	1.2	1.4	.0154	.0160	8.8	8.9	1.9	1.9	1.3	1.3
10	.0124	.0153	8.2	8.7	1.8	2.0	1.1	1.3	.0157	.0150	8.8	8.8	1.8	1.9	1.2	1.2
11	.0116	.0141	7.8	8.2	1.7	1.9	1.1	1.4	.0147	.0138	8.5	8.8	1.8	1.8	1.2	1.2
12	.0102	.0132	7.7	8.0	1.7	1.8	1.0	1.2	.....	.0108	.....	7.8	.....	1.6	.....	1.1
13	.0082	.0115	6.5	7.5	1.6	1.8	1.0	1.1	.....	.....	.....	.....	.....	.....	.....	.....

JULY 20

1	.....	0.0060	.....	5.6	.....	1.6	.....	0.8	.....	0.0046	.....	4.9	.....	1.4	.....	0.6
2	0.0098	.0133	7.1	8.0	1.8	1.9	1.0	1.2	0.0099	.0132	7.0	8.3	1.7	1.8	1.0	1.1
3	.0107	.0163	7.3	9.0	1.8	1.9	1.1	1.3	.0107	.0145	7.1	8.8	1.8	1.9	1.0	1.2
4	.0138	.0176	9.0	9.0	1.9	2.0	1.2	1.4	.0136	.0178	8.2	9.4	1.9	2.0	1.2	1.4
5	.0150	.0178	9.0	9.0	1.9	2.0	1.3	1.4	.0151	.0192	9.0	9.6	1.9	2.1	1.2	1.5
6	.0170	.0188	9.5	9.1	2.0	2.1	1.3	1.5	.0162	.0200	8.8	9.9	2.0	2.2	1.2	1.5
7	.0177	.0198	9.1	9.7	2.0	2.2	1.3	1.6	.0165	.0204	8.8	9.7	2.0	2.2	1.3	1.5
8	.0174	.0208	9.5	9.7	1.9	2.1	1.3	1.5	.....	.0196	.....	9.6	.....	2.1	.....	1.5
9	.0159	.0200	9.1	9.6	2.0	2.2	1.3	1.5	.0164	.0194	9.0	9.1	2.0	2.1	1.4	1.5
10	.0165	.0176	9.0	9.3	2.0	2.1	1.3	1.5	.0152	.0168	8.7	9.2	1.8	2.0	1.3	1.4
11	.0150	.0165	8.8	8.8	1.9	2.0	1.3	1.4	.0133	.0151	8.4	8.6	1.8	1.9	1.2	1.4
12	.0126	.0125	8.1	8.2	1.8	1.8	1.2	1.2	.0121	.....	8.0	.....	1.7	.....	1.2	.....

TABLE I.—*Normal growth of Hannchen barley in 12-hour periods from flowering to maturity, at Aberdeen, Idaho, in 1917*—Continued

JULY 21

Kernel No. from base of spike.	6 a. m.								7 p. m.							
	Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—		Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
	Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0093	0.0124	6.8	7.9	1.7	1.9	1.0	1.3	.....	0.0123	.....	8.1	.....	1.9	.....	1.2
3	.0139	.0165	8.3	8.8	1.8	1.9	1.2	1.3	0.0157	.0179	8.7	9.3	2.0	2.1	1.4	1.5
4	.0170	.0184	9.1	9.3	2.0	1.9	1.3	1.5	.0199	.0209	9.4	9.5	2.2	2.2	1.5	1.4
5	.0181	.0202	9.0	9.6	2.0	2.1	1.4	1.5	.0210	.0225	10.0	9.7	2.1	2.2	1.5	1.6
6	.0182	.0195	9.3	9.6	2.1	2.1	1.4	1.4	.0227	.0250	10.0	10.4	2.1	2.3	1.6	1.7
7	.0195	.0209	9.4	10.0	2.0	2.0	1.5	1.5	.0230	.0257	10.1	10.2	2.2	2.4	1.6	1.6
8	.0199	.0216	9.3	10.0	2.1	2.1	1.5	1.6	.0218	.0256	9.8	10.1	2.2	2.4	1.5	1.7
19	.0195	.0206	9.5	9.6	2.0	2.0	1.5	1.5	.0248	.0275	10.0	10.0	2.3	2.5	1.7	1.8
10	.0170	.0186	8.9	9.4	1.9	1.9	1.5	1.6	.0216	.0233	10.1	9.8	2.3	2.3	1.5	1.7
11	.0158	.0169	8.8	.....	1.9	2.0	1.3	1.4	.0212	.0234	9.3	9.1	2.3	2.4	1.5	1.8
12	.....	.....	.....	.....	.....	.....	.....	.....	.0187	.0237	9.2	9.6	2.2	2.4	1.5	1.7
13	.....	.....	.....	.....	.....	.....	.....	.....	.0168	.0193	8.6	8.6	2.0	2.2	1.4	1.5

JULY 22

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0160	.....	8.9	.....	2.0	.....	1.5
2	0.0190	0.0200	9.2	9.6	2.2	2.3	1.4	1.5	0.0190	.0205	9.1	9.5	2.2	2.3	1.4	1.5
3	.0248	.0225	9.9	10.1	2.3	2.4	1.6	1.6	.0232	.0253	9.9	10.6	2.4	2.4	1.6	1.7
4	.0272	.0282	10.2	10.5	2.5	2.5	1.7	1.8	.0270	.0264	10.2	10.5	2.6	2.5	1.6	1.6
5	.0291	.0294	10.2	10.3	2.6	2.6	1.9	1.8	.0278	.0289	10.2	10.5	2.5	2.8	1.8	1.9
6	.0279	.0293	10.1	10.1	2.6	2.5	1.9	1.8	.0284	.0289	10.4	10.4	2.6	2.6	1.8	1.9
7	.0276	.0289	9.8	10.2	2.7	2.6	1.8	1.8	.0280	.0284	10.0	10.5	2.7	2.6	1.8	1.8
8	.0283	.0282	9.5	10.1	2.7	2.5	1.9	1.8	.0271	.0287	9.6	10.0	2.6	2.8	1.7	1.8
9	.0256	.0306	9.5	10.1	2.6	2.6	1.6	1.9	.0282	.0282	9.6	10.2	2.6	2.7	1.8	1.8
10	.0248	.0277	9.3	9.9	2.5	2.6	1.8	1.8	.0266	.0270	9.4	9.9	2.6	2.5	1.7	1.9
11	.0203	.0257	8.8	9.8	2.4	2.6	1.5	1.7	.0241	.0253	9.4	9.7	2.5	2.5	1.7	1.7
12	.....	.0237	.....	9.6	.....	2.5	.....	1.7	.0217	.0258	8.9	10.0	2.3	2.6	1.6	1.7
13	.....	.0195	.....	9.0	.....	2.3	.....	1.5	.....	.0220	.....	8.8	.....	2.5	.....	1.7

JULY 23

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.0084	.....	7.4	.....	1.7	.....	1.2
2	.....	.....	.....	.....	.....	.....	.....	.....	0.0265	.0223	9.9	10.0	2.7	2.3	1.7	1.5
3	0.0282	0.0219	10.0	9.3	2.8	2.3	1.8	1.7	.0321	.0270	10.3	10.0	2.8	2.7	1.8	1.8
4	.0333	.0270	10.2	10.1	2.7	2.6	1.9	1.8	.0335	.0316	10.1	10.2	3.0	2.7	2.0	1.9
5	.0363	.0294	10.3	10.5	3.0	2.7	2.0	1.9	.0359	.0249	10.3	9.5	3.0	2.7	1.9	1.9
6	.0373	.0316	10.3	10.5	3.1	2.8	2.2	2.0	.0359	.0308	10.6	10.2	3.0	2.8	2.0	1.9
7	.0340	.0334	9.9	10.5	3.0	2.9	1.9	1.9	.0352	.0320	10.7	10.1	2.8	2.8	2.0	2.0
8	.0354	.0334	10.1	10.3	2.9	2.9	2.0	2.0	.0372	.0334	10.6	10.0	3.0	2.8	2.1	1.9
9	.0339	.0312	9.9	9.7	2.8	2.8	2.1	1.9	.0343	.0298	9.9	9.9	3.0	2.8	2.0	1.8
10	.0294	.0300	9.4	10.3	2.8	2.8	1.8	1.9	.0348	.0319	10.0	10.1	3.1	2.9	2.0	1.8
11	.0292	.0309	9.3	9.7	2.8	2.8	1.9	2.0	.0315	.0291	9.6	9.5	2.9	2.8	1.9	1.8
12	.0246	.0275	8.6	9.5	2.6	2.6	1.8	1.8	.0299	.0250	9.7	9.1	2.9	2.6	2.0	1.8

JULY 24

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0142	0.0212	8.4	9.0	2.3	2.4	1.4	1.5	.....	0.0173	.....	8.5	.....	2.0	.....	1.6
3	.0285	.0302	9.9	10.2	2.3	2.8	1.7	1.8	0.0291	.0301	9.6	9.4	2.7	2.8	1.8	2.0
4	.0323	.0328	9.8	10.2	2.9	2.8	1.8	1.9	.0335	.0333	10.3	10.0	3.0	2.8	2.0	2.1
5	.0346	.0328	10.4	10.3	2.9	2.8	1.9	1.8	.0361	.0372	10.0	10.2	3.0	3.1	2.0	2.0
6	.0359	.0345	10.3	10.2	3.0	2.9	1.9	1.9	.0371	.0383	10.2	10.4	3.0	3.0	2.0	2.0
7	.0357	.0332	10.2	10.3	2.9	2.9	1.8	2.0	.0353	.0387	10.0	10.2	2.9	3.0	2.0	2.2
8	.0355	.0342	9.9	10.2	2.9	2.8	2.0	2.0	.0379	.0381	10.1	10.2	3.0	3.2	2.0	2.0
9	.0328	.0340	9.8	10.4	3.0	2.8	1.8	2.0	.0322	.0398	10.1	10.0	2.9	3.1	1.9	2.0
10	.0342	.0333	9.1	9.9	3.0	2.9	1.9	2.1	.0338	.0384	9.6	10.1	2.8	3.1	1.9	2.0
11	.0319	.0328	9.4	10.2	3.0	2.9	1.6	2.0	.0344	.0363	9.3	9.8	3.0	3.0	2.0	2.1
12	.0276	.0304	9.0	9.7	2.9	2.8	1.8	2.0	.0278	.0351	9.3	9.6	2.8	2.9	2.0	1.9
13	.....	.0284	.....	8.8	.....	2.8	.....	1.9	.....	.0325	.....	9.9	.....	2.8	.....	1.8

TABLE I.—*Normal growth of Hannchen barley in 12-hour periods from flowering to maturity, at Aberdeen, Idaho, in 1917*—Continued

JULY 25

Kernel No. from base of spike.	6 a. m.								7 p. m.							
	Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—		Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
	Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0125	0.0092	7.5	7.4	1.7	1.5	1.4	1.0	0.0134	.....	7.8	.....	2.3	.....	1.5	.....
3	.0356	.0273	9.9	9.2	3.0	2.6	2.0	1.8	.0318	0.0307	9.6	9.8	3.0	2.9	1.8	2.0
4	.0386	.0308	10.5	9.8	3.1	2.8	2.2	1.9	.0391	.0359	10.2	10.5	3.3	3.0	2.1	2.0
5	.0449	.0366	10.3	10.4	3.3	3.1	2.3	2.0	.0387	.0387	10.0	10.4	3.2	3.2	2.2	2.1
6	.0445	.0377	10.3	10.3	3.3	3.0	2.2	2.1	.0388	.0397	10.1	10.4	3.2	3.2	2.3	2.0
7	.0440	.0367	10.3	10.1	3.2	3.0	2.2	2.1	.0390	.0386	10.0	10.0	3.3	3.2	2.1	2.0
8	.0357	.0394	9.8	10.6	3.0	3.1	1.9	1.9	.0400	.0409	9.9	10.2	3.3	3.2	2.3	2.1
9	.0438	.0384	9.9	10.2	3.4	3.0	2.3	2.1	.0384	.0390	9.5	9.7	3.3	3.1	2.3	2.0
10	.0349	.0378	9.8	10.0	2.9	2.9	2.1	2.0	.0358	.0371	9.4	9.9	3.2	3.1	2.1	2.1
11	.0388	.0374	9.4	10.2	3.3	3.0	2.2	2.1	.0334	.0333	9.1	9.3	3.0	3.1	2.1	2.1
12	.0343	.0350	9.1	9.8	3.0	2.9	2.0	2.1	.0314	.....	9.0	.....	3.0	.....	2.0	.....
13	.....	.0332	.....	9.2	.....	3.1	.....	2.1	.....	.....	.....	.....	.....	.....	.....	.....

JULY 26

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0271	0.0305	9.5	9.4	2.4	2.8	1.7	1.9	0.0206	0.0174	8.3	8.5	2.5	2.4	1.6	1.4
3	.0346	.0320	9.8	9.5	2.8	2.6	1.8	1.8	.0406	.0399	10.1	10.0	3.3	3.4	2.0	2.0
4	.0407	.0395	10.4	10.1	3.2	3.0	2.1	2.0	.0445	.0420	10.3	9.9	3.4	3.3	2.0	2.2
5	.0419	.0418	10.5	9.9	3.2	3.1	2.1	2.2	.0445	.0451	10.4	9.8	3.3	3.3	2.4	2.0
6	.0403	.0408	10.1	9.7	3.1	3.2	2.1	2.1	.0445	.0450	10.4	10.2	3.3	3.3	2.2	2.1
7	.0359	.0398	10.2	9.9	2.8	3.2	2.1	2.2	.0406	.0457	9.8	9.4	3.2	3.3	2.1	2.3
8	.0400	.0400	10.0	10.0	3.1	3.0	2.2	2.2	.0436	.0443	10.2	10.1	3.4	3.3	2.2	2.4
9	.0366	.0378	9.7	9.2	3.0	3.1	2.1	2.2	.0428	.0416	10.4	9.8	3.3	3.4	2.2	2.3
10	.0358	.0375	10.0	9.5	3.0	3.1	1.8	2.0	.0409	.0422	10.2	9.6	3.2	3.4	2.1	2.3
11	.0335	.0269	9.5	8.5	3.2	2.6	2.0	1.9	.0360	.0397	9.4	9.4	3.2	3.3	2.1	2.0
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.0336	.....	8.9	.....	2.9	.....	2.0

JULY 27

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0194	0.0387	8.2	10.2	3.5	3.2	1.5	2.1	0.0346	.....	9.6	.....	3.0	.....	2.2	.....
3	.0405	.0479	10.0	10.6	3.1	3.2	1.9	2.2	.0431	0.0406	9.8	9.9	3.1	3.3	2.2	2.2
4	.0417	.0489	10.4	10.6	3.5	3.5	2.1	2.2	.0479	.0436	10.7	10.3	3.4	3.3	2.1	2.2
5	.0499	.0481	10.6	10.5	3.4	3.4	2.3	2.4	.0467	.0498	10.8	10.1	3.3	3.4	2.0	2.3
6	.0495	.0483	10.4	10.4	3.4	3.5	2.3	2.4	.0483	.0514	10.5	10.7	3.2	3.3	2.3	2.4
7	.0501	.0483	10.3	10.4	3.4	3.5	2.2	2.2	.0497	.0491	10.5	9.5	3.4	3.2	2.5	2.3
8	.0498	.0465	10.2	10.1	3.4	3.4	2.3	2.1	.0498	.0499	10.4	10.1	3.3	3.5	2.2	2.5
9	.0487	.0445	10.2	10.1	3.3	3.3	2.3	2.3	.0465	.0481	10.3	10.2	3.3	3.5	2.2	2.4
10	.0480	.0440	9.9	9.9	3.4	3.2	2.5	2.4	.0479	.0435	10.0	10.1	3.5	3.2	2.4	2.2
11	.0443	.0430	9.8	9.5	3.3	3.4	2.5	2.3	.0455	.0429	10.0	9.5	3.4	3.3	2.4	2.2
12	.0435	.0408	9.2	9.5	3.3	3.0	2.3	2.4	.0433	.0324	9.8	8.7	3.4	2.7	2.3	2.1
13	.0330	.....	8.6	.....	3.0	.....	2.1	.....	.0392	.....	9.3	.....	3.2	.....	2.3	.....
14	.....	.....	.....	.....	.....	.....	.....	.....	.0390	.....	9.1	.....	3.3	.....	2.1	.....

JULY 28

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	.....	0.0289	.....	8.5	.....	3.0	.....	1.9	0.0417	0.0359	10.0	9.9	3.4	3.2	2.1	1.9
3	0.0352	.0491	9.6	10.1	3.3	3.5	1.9	2.2	.0477	.0484	9.8	10.5	3.5	3.4	2.4	2.3
4	.0417	.0512	10.1	10.3	3.2	3.5	2.0	2.3	.0531	.0533	10.7	10.2	3.5	3.5	2.5	2.5
5	.0471	.0523	9.9	10.5	3.5	3.5	2.2	2.3	.0556	.0544	10.2	10.5	3.7	3.7	2.6	2.5
6	.0477	.0578	10.1	10.6	3.4	3.7	2.3	2.5	.0519	.0549	10.2	10.4	3.7	3.5	2.5	2.4
7	.0500	.0535	10.0	10.4	3.5	3.7	2.2	2.5	.0540	.0529	10.2	10.2	3.6	3.6	2.5	2.4
8	.0503	.0560	10.2	10.5	3.6	3.7	2.2	2.6	.0510	.0521	10.0	10.2	3.4	3.4	2.5	2.5
9	.0479	.0544	10.4	10.4	3.4	3.7	2.2	2.5	.0467	.0487	10.3	10.3	3.3	3.5	2.3	2.4
10	.0494	.0526	9.9	10.1	3.5	3.6	2.2	2.4	.0479	.0492	10.0	10.1	3.5	3.5	2.4	2.5
11	.0505	.0529	9.9	9.7	3.5	3.6	2.3	2.5	.0467	.0493	9.8	9.7	3.3	3.6	2.3	2.6
12	.0446	.0487	9.7	10.0	3.4	3.6	2.1	2.5	.0426	.0456	10.0	9.8	3.4	3.4	2.2	2.5
13	.0427	.0445	9.6	9.6	3.4	3.4	2.2	2.2	.....	.0406	.....	9.2	.....	3.3	.....	2.3
14	.0395	.0390	9.4	9.0	3.3	3.2	2.3	2.2	.....	.....	.....	.....	.....	.....	.....	.....

TABLE I.—*Normal growth of Hannchen barley in 12-hour periods from flowering to maturity, at Aberdeen, Idaho, in 1917*—Continued

JULY 29

Kernel No. from base of spike	6 a. m.								7 p. m.							
	Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—		Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
	Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0228	.....	3.5	.....	2.7	.....	1.6	.....	0.0377	0.0434	9.8	9.8	3.0	3.5	2.0	2.3
3	.0492	0.0385	9.6	9.7	3.4	3.3	2.3	2.0	.0507	.0482	10.0	9.8	3.6	3.5	2.5	2.5
4	.0513	.0485	9.3	10.3	3.7	3.5	2.4	2.1	.0532	.0537	10.1	10.3	3.6	3.5	2.5	2.5
5	.0550	.0502	10.4	10.3	3.7	3.6	2.5	2.4	.0537	.0532	10.1	10.0	3.5	3.6	2.5	2.5
6	.0550	.0496	9.6	10.2	3.8	3.6	2.5	2.4	.0538	.0522	10.3	10.3	3.5	3.7	2.5	2.4
7	.0504	.0511	10.0	9.8	3.4	3.7	2.2	2.5	.0514	.0513	9.7	10.1	3.4	3.5	2.5	2.4
8	.0492	.0497	10.1	10.3	3.4	3.4	2.3	2.3	.0521	.0522	10.1	10.1	3.6	3.6	2.6	2.6
9	.0487	.0506	9.9	9.8	3.6	3.5	2.6	2.5	.0520	.0492	9.9	10.4	3.4	3.5	2.6	2.5
10	.0498	.0485	9.4	10.0	3.7	3.5	2.5	2.5	.0465	.0502	9.4	9.7	3.4	3.6	2.4	2.6
11	.0465	.0446	9.6	9.6	3.5	3.4	2.3	2.4	.0448	.0418	9.2	8.7	3.4	3.4	2.4	2.4
12	.0406	.0405	9.0	9.0	3.3	3.3	2.4	2.4	.....	.....	.....	.....	.....	.....	.....	.....

JULY 30

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0478	0.0430	9.8	10.2	3.5	3.3	2.4	2.3	0.0474	0.0426	9.0	8.8	3.3	3.4	2.3	2.3
3	.0509	.0517	10.1	10.2	3.7	3.7	2.3	2.5	.0565	.0517	9.6	9.2	3.7	3.6	2.5	2.5
4	.0557	.0550	11.0	10.5	3.7	3.6	2.4	2.4	.0588	.0553	9.7	9.2	3.7	3.8	2.5	2.5
5	.0574	.0559	10.8	10.6	3.7	3.6	2.4	2.5	.0600	.0589	9.8	9.5	3.7	3.7	2.5	2.6
6	.0579	.0541	10.7	11.0	3.7	3.6	2.5	2.5	.0620	.0560	9.8	9.2	3.8	3.7	2.6	2.7
7	.0551	.0535	10.2	10.7	3.6	3.6	2.5	2.4	.0600	.0577	10.0	9.1	3.7	3.8	2.6	2.7
8	.0498	.0500	10.0	10.1	3.4	3.5	2.5	2.3	.0627	.0534	9.9	8.8	3.8	3.5	2.7	2.8
9	.0520	.0499	10.0	10.3	3.4	3.5	2.5	2.5	.0600	.0521	9.8	8.6	3.7	3.7	2.7	2.7
10	.0487	.0485	10.0	10.3	3.4	3.4	2.5	2.4	.0531	.0500	9.0	8.6	3.7	3.5	2.5	2.6
11	.....	.0495	.....	9.5	.....	3.8	.....	2.5	.0579	.0455	9.4	8.3	3.7	3.4	2.6	2.5
12	.....	.0399	.....	9.6	.....	3.4	.....	2.3	.0543	.....	9.1	.....	3.4	.....	2.6	.....
13	.....	.....	.....	.....	.....	.....	.....	.....	.0478	.....	8.5	.....	3.5	.....	2.5	.....

JULY 31

	6 a. m.								6.30 p. m. ‡							
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0409	0.0443	7.9	8.9	3.3	3.4	2.4	2.4	0.0463	0.0374	7.5	8.0	3.5	3.3	2.4	2.3
3	.0511	.0503	9.2	9.1	3.8	3.5	2.5	2.4	.0545	.0493	8.1	9.0	3.7	3.5	2.6	2.5
4	.0559	.0579	9.0	9.8	3.8	3.7	2.6	2.5	.0615	.0554	9.5	8.3	3.7	3.7	2.8	2.7
5	.0565	.0575	9.0	9.7	3.7	3.7	2.5	2.5	.0600	.0565	9.2	9.0	3.7	3.7	2.7	2.7
6	.0561	.0582	9.1	9.7	3.7	3.7	2.6	2.5	.0588	.0552	9.2	9.0	3.7	3.6	2.7	2.6
7	.0552	.0550	9.0	9.7	3.8	3.5	2.6	2.5	.0593	.0552	9.5	9.1	3.7	3.7	2.7	2.5
8	.0525	.0575	8.7	9.6	3.7	3.5	2.6	2.6	.0574	.0553	9.3	8.9	3.7	3.7	2.7	2.5
9	.0521	.0581	8.9	9.3	3.5	3.5	2.6	2.6	.0537	.0515	8.7	8.5	3.6	3.4	2.5	2.5
10	.0487	.0557	8.7	9.1	3.5	3.5	2.6	2.6	.0533	.0512	8.5	8.7	3.5	3.6	2.6	2.6
11	.0488	.0552	8.4	9.2	3.5	2.5	2.5	2.6	.0510	.0450	8.7	8.2	3.7	3.5	2.6	2.4
12	.0388	.0534	7.9	9.1	3.2	3.5	2.3	2.6	.....	.0370	.....	7.6	.....	3.0	.....	2.4
13	.....	.0469	.....	8.8	.....	3.3	.....	2.5	.....	.....	.....	.....	.....	.....	.....	.....
14	.....	.0361	.....	8.0	.....	3.0	.....	2.3	.....	.....	.....	.....	.....	.....	.....	.....

AUGUST 1

1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0351	0.0451	8.4	8.8	3.2	3.5	2.0	2.3	.....	0.0321	.....	8.0	.....	3.0	.....	1.9
3	.0515	.0554	9.2	9.5	3.6	3.7	2.4	2.3	0.0500	.0525	9.1	9.0	3.3	3.7	2.3	2.3
4	.0577	.0625	9.8	9.6	3.5	3.7	2.5	2.6	.0566	.0597	9.0	9.6	3.6	3.6	2.6	2.7
5	.0614	.0611	9.5	9.4	3.7	3.8	2.6	2.6	.0575	.0604	9.2	9.3	3.8	3.8	2.6	2.7
6	.0588	.0599	9.5	9.8	3.8	3.8	2.5	2.6	.0598	.0589	9.3	9.6	3.9	3.8	2.6	2.7
7	.0583	.0615	9.2	9.3	3.7	3.9	2.6	2.6	.0598	.0589	9.4	9.0	3.7	3.8	2.5	2.6
8	.0581	.0594	9.4	9.4	3.6	3.7	2.6	2.5	.0578	.0596	9.0	9.1	3.7	3.8	2.6	2.7
9	.0589	.0589	9.3	9.4	3.8	3.7	2.6	2.6	.0571	.0589	9.3	9.3	3.7	3.8	2.7	2.5
10	.0563	.0557	9.4	9.2	3.7	2.7	2.6	2.6	.0571	.0558	9.0	9.0	3.7	3.6	2.7	2.5
11	.0550	.0521	9.1	8.7	3.6	3.6	2.6	2.4	.0536	.0556	9.0	9.0	3.7	3.7	2.6	2.5
12	.0527	.0473	9.0	8.4	3.5	3.4	2.5	2.5	.0500	.0505	8.6	8.6	3.3	3.5	2.6	2.4
13	.0514	.....	8.6	.....	3.5	.....	2.5	.....	.0454	.0443	8.3	8.4	3.4	3.2	2.4	2.4
14	.0450	.....	8.4	.....	3.3	.....	2.4	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE I.—*Normal growth of Hannchen barley in 12-hour periods from flowering to maturity, at Aberdeen, Idaho, in 1917*—Continued

AUGUST 2

Kernel No. from base of spike.	6 a. m.								7 p. m.							
	Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—		Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
	Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0302	.....	7.7	.....	2.8	.....	2.0	.....	.....	0.0404	.....	8 1	.....	3.3	.....	2.3
3	.0500	0.0528	8.9	9.1	3.6	3.4	2.4	2.4	0.0426	.0483	8.3	8.7	3.3	3.6	2.5	2.3
4	.0617	.0596	9.6	9.4	3.8	3.8	2.5	2.6	.0546	.0543	8.8	9.0	3.6	3.7	2.7	2.5
5	.0611	.0620	9.6	9.5	3.8	3.8	2.6	2.7	.0553	.0571	9.4	9.1	3.9	3.8	2.6	2.6
6	.0620	.0644	9.8	9.6	3.8	3.8	2.6	2.7	.0566	.0566	9.1	9.1	3.7	3.6	2.5	2.6
7	.0579	.0600	9.4	9.3	3.7	3.8	2.5	2.6	.0546	.0586	9.0	9.0	3.7	3.8	2.5	2.7
8	.0601	.0610	8.8	9.4	3.7	3.6	2.5	2.6	.0558	.0561	9.0	9.1	3.6	3.7	2.6	2.8
9	.0577	.0592	9.1	9.2	3.7	3.7	2.6	2.7	.0547	.0548	9.1	8.7	3.6	3.5	2.5	2.7
10	.0595	.0572	9.0	9.0	3.8	3.8	2.8	2.7	.0508	.0500	8.7	8.6	3.5	3.5	2.5	2.5
11	.0574	.0515	9.2	8.8	3.5	3.5	2.5	2.5	.0465	.0464	8.1	8.3	3 5	3 5	2 5	2.5
12	.0476	.0521	8.7	8.7	3.5	3.5	2.5	2.7	.0371	.0387	7.8	7.5	3.2	3.2	2.4	2.2
13	.0489	.0429	8.5	8.0	3.5	3.3	2.5	2.4	.....	.....	.....	.....	.....	.....	.....	.....

AUGUST 3

	6 a. m.								6.45 p. m.							
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0363	.....	8.0	.....	3.3	.....	2.2	.....	0.0521	0.0425	9.2	7.9	3.3	3.3	2.5	2.5
3	.0510	0.0510	9.2	8.8	3.6	3.5	2.3	2.5	.0639	.0548	9.1	9.8	3.8	3.7	2.7	2.7
4	.0560	.0572	9.5	9.0	3.5	3.8	2.4	2.6	.0644	.0565	9.4	9.0	4.0	3.6	2.7	2.6
5	.0573	.0595	9.2	9.6	3.6	3.8	2.6	2.6	.0650	.0558	9.6	8.8	3.7	3.6	2.6	2.5
6	.0621	.0608	9.2	9.2	3.7	3.8	2.7	2.7	.0651	.0551	9.4	9.0	3.8	3.6	2.5	2.5
7	.0580	.0602	9.0	9.3	3.6	3.8	2.6	2.5	.0633	.0554	9.3	8.7	3.8	3.7	2.8	2.6
8	.0573	.0579	9.1	9.2	3.6	3.5	2.5	2.5	.0651	.0540	9.3	8.5	3.9	3.6	2.8	2.7
9	.0602	.0583	8.8	9.0	3.6	3.5	2.5	2.6	.0629	.0513	9.2	8.0	3.8	3.5	2.6	2.8
10	.0600	.0577	8.7	8.9	3.7	3.8	2.7	2.6	.0599	.0476	9.1	7.8	3.7	3.3	2.7	2.5
11	.0531	.0545	8.7	8.7	3.5	3.7	2.6	2.6	.0591	.0437	8.8	7.6	3.7	3.4	2.7	2.5
12	.0531	.0504	8.7	8.4	3.6	3.7	2.6	2.6	.0536	.....	8.4	.....	3.5	.....	2.7	.....
13	.0532	.0507	8.5	8.8	3.6	3.2	2.7	2.3	.....	.....	.....	.....	.....	.....	.....	.....
14	.0452	.....	8.2	.....	3.2	.....	2.6	.....	.....	.....	.....	.....	.....	.....	.....	.....

AUGUST 4

	5.45 a. m.								6.45 p. m.							
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0454	0.0409	8.0	8.3	3.4	3.4	2.4	2.3	0.0300	0.0386	7.8	8.2	2.8	3.1	2.0	2.1
3	.0537	.0550	8.7	8.9	3.6	3.7	2.4	2.6	.0567	.0623	9.0	9.3	3.7	3.7	2.6	2.7
4	.0594	.0600	9.1	9.3	3.7	3.8	2.7	2.5	.0656	.0668	9.3	9.7	3.9	3.8	2.7	2.6
5	.0605	.0596	9.3	9.6	3.7	3.7	2.8	2.6	.0629	.0675	9.6	9.8	3.7	3.7	2.8	2.7
6	.0577	.0626	9.2	9.6	3.6	3.7	2.6	2.7	.0629	.0645	9.3	9.6	3.8	3.7	2.8	2.7
7	.0580	.0617	9.1	9.6	3.5	3.8	2.6	2.9	.0660	.0655	9.2	9.4	3.7	3.7	2.9	2.7
8	.0539	.0592	9.0	9.0	3.4	3.8	2.5	2.6	.0614	.0660	9.4	9.4	3.7	3.8	2.8	2.8
9	.0556	.0557	8.8	9.1	3.7	3.5	2.7	2.7	.0614	.0633	9.1	9.1	3.7	3.7	2.8	2.7
10	.0539	.0565	9.0	9.0	3.7	3.5	2.8	2.8	.0546	.0617	9.0	9.1	3.5	3.8	2.7	2.7
11	.0475	.0550	8.2	9.0	3.5	3.5	2.6	2.7	.0546	.0596	8.9	9.0	3.7	3.7	2.5	2.8
12	.0400	.0480	7.8	8.3	3.2	3.4	2.4	2.6	.0532	.0582	8.5	9.0	3.5	3.7	2.6	2.7
13	.....	.....	.....	.....	.....	.....	.....	.....	.0448	.0548	7.9	8.5	3.3	3.5	2.6	2.8
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.0483	.....	8.3	.....	3.4	.....	2.6

TABLE I.—*Normal growth of Hannchen barley in 12-hour periods from flowering to maturity, at Aberdeen, Idaho, in 1917*—Continued

AUGUST 5

Kernel No. from base of spike.	6 a. m.								6.30 p. m.							
	Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—		Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
	Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0252	0.0461	7.2	8.1	2.6	3.4	1.9	2.4	0.0300	.....	7.0	.....	3.0	.....	2.0	.....
3	.0590	.0543	9.1	8.8	3.8	3.6	2.7	2.5	.0538	0.0528	8.9	8.4	3.5	3.5	2.3	2.5
4	.0631	.0601	8.9	8.8	3.8	3.7	2.8	2.8	.0597	.0592	8.7	9.2	3.6	3.7	2.5	2.6
5	.0637	.0559	9.3	9.2	3.8	3.5	2.7	2.7	.0635	.0596	9.3	9.0	3.9	3.5	2.6	2.7
6	.0671	.0585	9.4	8.9	3.8	3.7	2.8	2.7	.0600	.0614	8.7	9.1	3.8	3.7	2.6	2.8
7	.0627	.0562	8.7	8.7	3.9	3.7	2.7	2.6	.0639	.0614	8.8	9.0	3.7	3.7	2.8	2.7
8	.0609	.0535	9.1	8.7	3.7	3.5	2.8	2.6	.0598	.0588	8.6	8.9	3.7	3.7	2.7	2.7
9	.0593	.0527	9.0	8.5	3.7	3.6	2.7	2.6	.0587	.0551	8.8	8.2	3.8	3.4	2.6	2.6
10	.0564	.0503	8.5	8.4	3.6	3.5	2.7	2.6	.0574	.0542	8.7	8.5	3.7	3.5	2.7	2.7
11	.0507	.0446	8.3	7.7	3.4	3.4	2.7	2.6	.0539	.0466	8.5	8.0	3.4	3.4	2.6	2.5
12	.....	.....	.....	.....	.....	.....	.....	.....	.0515	.0441	8.3	7.6	3.4	3.4	2.5	2.4
13	.....	.....	.....	.....	.....	.....	.....	.....	.0456	.....	8.1	.....	3.3	.....	2.5	.....

AUGUST 6

	6 a. m.								6.40 p. m.							
1	.....	.....	.....	.....	.....	.....	.....	.....	0.0231	.....	7.2	.....	2.6	.....	1.8	.....
2	0.0528	0.0560	8.9	8.9	3.7	3.7	2.5	2.6	.0534	0.0513	8.7	8.7	3.5	3.5	2.5	2.5
3	.0639	.0606	9.4	8.9	3.8	3.8	2.7	2.8	.0617	.0578	9.2	8.9	3.6	3.6	2.5	2.8
4	.0634	.0615	9.4	9.0	3.8	3.7	2.8	2.7	.0648	.0580	9.2	8.8	3.7	3.5	2.7	2.8
5	.0657	.0622	9.6	9.4	3.8	3.8	2.8	2.8	.0624	.0566	9.3	8.9	3.6	3.5	2.7	2.7
6	.0675	.0634	9.7	9.1	3.9	3.8	2.9	2.7	.0624	.0553	9.1	8.6	3.5	3.5	2.7	2.7
7	.0628	.0602	9.1	8.9	3.8	3.6	2.7	2.7	.0613	.0561	8.7	8.8	3.7	3.5	2.7	2.7
8	.0626	.0566	9.4	8.9	3.8	3.6	2.9	2.6	.0589	.0512	9.0	8.3	3.5	3.4	2.7	2.6
9	.0623	.0550	9.0	8.4	3.7	3.5	2.9	2.6	.0576	.0476	8.8	8.1	3.5	3.3	2.7	2.6
10	.0580	.0528	8.6	8.2	3.6	3.5	2.8	2.6	.0509	.0479	8.5	8.1	3.4	3.3	2.7	2.6
11	.0576	.0513	8.7	8.2	3.6	3.5	2.6	2.7	.0491	.0330	8.3	7.6	3.4	2.9	2.6	2.3
12	.0534	.0487	8.5	8.2	3.5	3.5	2.7	2.6	.0444	.....	8.1	.....	3.2	.....	2.4	.....

AUGUST 7

	6 a. m.								7 p. m.							
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	0.0571	0.0568	8.6	8.3	3.7	3.6	2.5	2.6	0.0541	0.0523	8.7	8.5	3.7	3.5	2.6	2.5
3	.0616	.0641	9.5	9.0	3.7	3.9	2.5	2.8	.0567	.0592	9.0	8.9	3.6	3.8	2.8	2.8
4	.0657	.0646	9.4	9.1	3.7	3.8	2.6	2.8	.0579	.0619	9.0	9.0	3.7	3.8	2.7	2.8
5	.0699	.0623	9.6	9.4	3.8	3.6	3.0	2.6	.0561	.0626	8.5	8.9	3.5	3.7	2.6	2.7
6	.0672	.0623	9.4	9.3	3.6	3.7	2.9	2.7	.0605	.0618	9.3	9.0	3.7	3.7	2.8	2.7
7	.0674	.0623	9.2	8.8	3.7	3.7	2.8	2.8	.0589	.0610	8.9	8.9	3.7	3.7	2.7	2.8
8	.0639	.0627	9.0	8.7	3.7	3.6	2.8	2.9	.0575	.0600	8.7	9.0	3.5	3.7	2.6	2.8
9	.0592	.0585	9.1	8.8	3.5	3.7	2.6	2.6	.0558	.0597	8.7	8.5	3.5	3.7	2.8	2.7
10	.0626	.0570	8.7	8.5	3.8	3.6	2.7	2.8	.0559	.0573	8.5	8.5	3.5	3.5	2.8	2.6
11	.0591	.0533	8.5	8.5	3.7	3.6	2.6	2.7	.0480	.0516	8.0	8.5	3.4	3.2	2.6	2.6
12	.0576	.0465	8.4	8.3	3.5	3.4	2.7	2.5	.0432	.0488	8.2	8.0	3.2	3.4	2.5	2.5
13	.0480	.....	8.2	.....	3.4	.....	2.6	.....	.....	.0399	.....	8.0	.....	3.1	.....	2.3

TABLE I.—*Normal growth of Hannchen barley in 12-hour periods from flowering to maturity, at Aberdeen, Idaho, in 1917*—Continued

AUGUST 8

Kernel No. from base of spike.	6 a. m.								6.40 p. m.							
	Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike.		Weight of kernel on spike—		Length of kernel on spike—		Lateral diameter of kernel on spike—		Dorso-ventral diameter of kernel on spike—	
	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
	Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
1	0.0363	0.0243	7.7	6.7	3.0	2.7	2.1	1.9	.....	.....	.....	.....	.....	.....	.....	.....
2	.0595	.0532	8.6	8.0	3.6	3.6	2.7	2.5	.....	0.0440	.....	7.8	.....	3.2	.....	2.5
3	.0613	.0618	8.8	8.7	3.6	3.8	2.6	2.8	0.0502	.0571	8.4	8.4	3.5	3.5	2.7	2.6
4	.0655	.0634	9.3	8.9	3.8	3.7	2.9	2.7	.0578	.0609	8.6	9.0	3.6	3.6	2.7	2.7
5	.0682	.0647	9.2	9.2	3.6	3.8	2.7	2.8	.0590	.0570	9.0	8.8	3.6	3.6	2.7	2.6
6	.0659	.0624	9.0	8.7	3.7	3.7	2.7	2.8	.0569	.0576	8.8	8.8	3.5	3.5	2.6	2.6
7	.0659	.0626	9.0	8.8	3.6	3.6	2.8	2.8	.0581	.0554	8.8	8.9	3 6	3.5	2.7	2.6
8	.0634	.0615	8.9	8.6	3.6	3.7	2.7	2.8	.0565	.0553	8.6	8.5	3.5	3.5	2.6	2.7
9	.0642	.0604	8.6	8.4	3.7	3.7	2.8	2.7	.0508	.0539	8.6	8.6	3.4	3.4	2.5	2.6
10	.0607	.0590	8.2	8.4	3.6	3.7	2.8	2.8	.0511	.0507	8.4	8.4	3.5	3.5	2.6	2.7
11	.0585	.0500	8.6	8.0	3.5	3.5	2.7	2.4	.0423	.0412	7.8	7.6	3.2	3.1	2.4	2.5
12	.0546	.0453	8.1	7.7	3.4	3.3	2.7	2.4	.....	.....	.....	.....	.....	.....	.....	.....
13	.0420	.....	7.7	.....	3.1	.....	2.5	.....	.....	.....	.....	.....	.....	.....	.....	.....

The course of growth is more apparent in Table II, where the results have been summarized in 24-hour periods. That is, the weights and measurements of all the kernels on each spike of the two samples have been averaged and these averages placed opposite the dates. No summary was made for the data in 12-hour periods, because the daily changes of dimension after the first few days were too slight to be shown in so short a period. Growth in length in the early stages, however, is perfectly apparent in 12 hours.

TABLE II.—*Average wet weight, length, lateral diameter, and dorsoventral diameter of kernels of Hannchen barley in 24-hour periods from flowering to maturity at Aberdeen, Idaho, in 1917*

Date.		Wet weight.	Length.	Lateral diameter.	Dorso-ventral diameter.	Date.		Wet weight.	Length.	Lateral diameter.	Dorso-ventral diameter.
		Mgm.	*Mm.*	*Mm.*	*Mm.*			*Mgm.*	*Mm.*	*Mm.*	*Mm.*
July	15	1.9	2.27	1.26	.....	July	28	48.2	10.02	3.47	2.33
	16	3.0	2.88	1.32	0.74		29	49.0	9.84	3.50	2.42
	17	4.5	3.93	1.39	.82		30	53.0	9.99	3.59	2.50
	18	8.0	6.05	1.57	.90		31	52.2	8.83	3.56	2.54
	19	12.7	7.91	1.79	1.16	Aug.	1	54.8	9.10	3.62	2.51
	20	15.8	8.78	1.94	1.30		2	53.3	8.87	3.59	2.54
	21	19.2	9.32	2.10	1.48		3	55.8	8.87	3.61	2.59
	22	25.7	9.81	2.51	1.71		4	56.3	8.96	3.60	2.64
	23	31.0	9.96	2.80	1.90		5	55.9	8.66	3.60	2.62
	24	32.7	9.83	2.86	1.90		6	56.6	8.78	3.57	2.67
	25	36.0	9.80	3.02	2.05		7	58.0	8.77	3.60	2.68
	26	38.2	9.77	3.09	2.06		8	56.1	8.53	3.53	2.64
	27	44.6	9.98	3.30	2.25						

The significance of the data in Table II is, perhaps, more easily seen in figure 1. The most surprising feature shown by this figure is the remarkably rapid growth in length following fertilization. In the two days from the second to the fourth after fertilization, half the growth in length occurs. The insufficiency of 3-day intervals in sampling at this stage is obvious. Distinct growth is shown in 12-hour periods, and it is probable that consistent increase would be revealed in 6-hour periods. The kernel reached its maximum length by the end of 7 days in each year. After the peak of length is reached, there is a gradual decrease to maturity. This is discussed later in connection with figure 4.

The lateral diameter exhibits its most rapid increase as soon as the rate of the growth in length diminishes. This increase continues until about the fifteenth day, after which the lateral diameter remains more or less stationary. The dorsoventral diameter, on the other hand, continues to increase almost until maturity. The increase is somewhat less than in the lateral diameter, there being a greater divergence in the growth curves at the end of the growing period than at the beginning. The effect of the better irrigation in 1916 is apparent throughout the period of growth. There is a possibility that the 1916 samples are a few hours farther advanced throughout the series because of differences in temperature or other factors at flowering time. While growth itself is not so easily affected, fertilization is often hastened or delayed many hours by conditions in the environment.

During the early growth of the kernel the ovary tip undergoes a sympathetic development. When the kernel is first developing, the growth is largely in the pericarp. Some of the tissues surrounding the embryo sac and the ovary walls of the same region develop rapidly and are to be found in the ripened caryopsis. For some reason, the tissues above the embryo sac are temporarily stimulated, forming a body at the end of the kernel, which is referred to here as the ovary tip. This growth, which may be seen in Plates 83 and 84, is of importance because it introduces an error in the measurement of length. After the growth of the first few days, this organ remains stationary in size for a while and finally is largely resorbed. In figure 1 it will be seen that it was possible to measure the kernel proper without this tip by the fifteenth day after flowering. The records of lengths until that time included the ovary tip. The lateral and dorsoventral diameters of the ovary tip are shown in figure 4. It is probable that the length of the kernel proper increased somewhat after it had apparently reached its maximum by invading the tissues of the ovary tip. This tissue is probably partially responsible for the difference of measurements in the first 15 days of the two years. A second factor in the error lies in the softness of the structure at the base of the kernel. In the early stages of growth it is exceedingly difficult to place the caliper bar at exactly the right point, and in 1917 the kernels may have been measured more closely than in 1916. The difference of the

two years, however, is less than 0.5 mm., so that the data coincide far beyond any reasonable expectation.

The reason that errors in this connection are suggested is that it is not plausible that the differences in soil or water would affect the kernels by

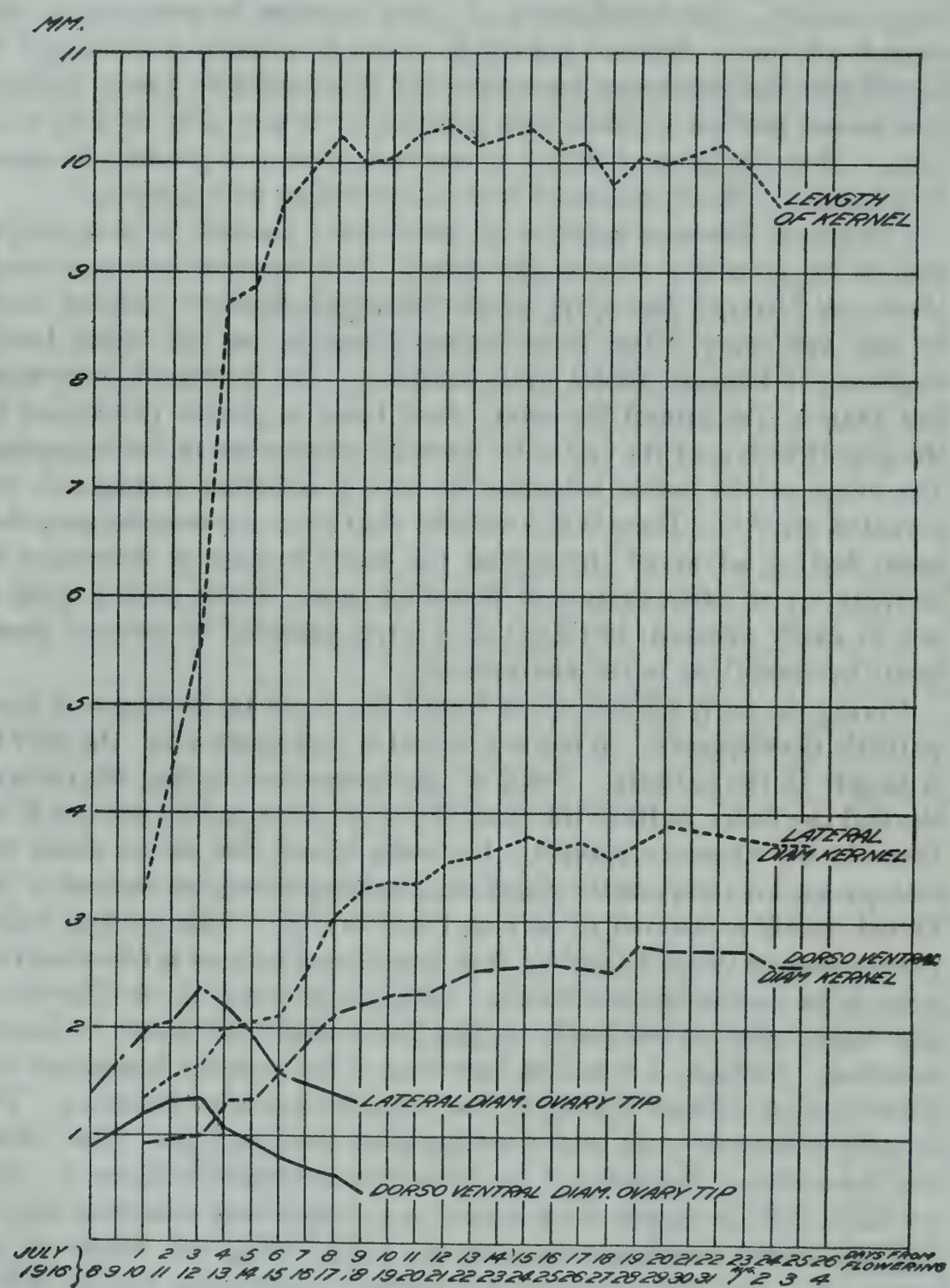

FIG. 4.—Graph showing lateral and dorsoventral diameters of the ovary tip as compared with length, lateral diameter, and dorseventral diameter of the kernel for the 26 days following flowering in 1916.

this time, since there obviously is no insufficiency of nutrients for this primary growth. These data have an incidental bearing on the value of observations on the length and diameter of kernels. Such observations are used frequently to identify varieties. In 1914, the author (2) stated

that length was more dependable than lateral diameter and that lateral diameter was more dependable than dorsoventral diameter in the description of types. The same observations have been made, presumably, by many others. The growth curves confirm this opinion. The length is quickly attained and should vary little with season. The lateral diameter reaches its maximum more slowly than the length, but much sooner than the dorsoventral diameter, which is dependent upon conditions throughout the growing season for the fulfillment of its maximum possibilities.

As has been inferred before, the kernels at the base and the tip of the spike are more variable than those near the center. With the increase of the number of kernels on the spike those at the extremes are likely to suffer from competition. On any spike, if nutrition at any time becomes insufficient, the basal and the apical kernels are the first to be affected. Averages which include these kernels show greater fluctuations than those from which they are excluded. This variation was overcome partially by including in the averages no basal kernels which weighed less than half as much as the kernel next above. Since this does not entirely overcome the difficulty the average length, lateral diameter, and dorsoventral diameter of kernels 6, 7, and 8 are plotted in figure 5 as an illustration of the behavior of more typical kernels. It will be seen that the daily fluctuations are much reduced.

EFFECT OF POSITION OF KERNEL ON GROWTH

There are two main factors that affect the relative size of kernels. These are age and the position of the kernel on the spike. The relative importance of these factors varies with the stage of growth. The age of the kernel depends on the time of flowering. The florets of a spike are not all fertilized on the same day. The earliest flowers usually are those located about two-thirds the distance from the base of the spike to the tip. The last to fertilize are the extreme basal and apical florets. The largest florets are found one-third the length of the spike from the base. Presumably, the kernels found in these florets receive more nourishment than those at the tip, especially toward the end of the growing period. The length of each kernel on one side of the spike is shown by days in figure 6. The growth is practically completed in these eight days. As will be seen, florets 8, 9, and 10 are the first to fertilize and to begin growth. By the third day these three kernels have reached their greatest relative advancement. After the second day there is a gradual shift in the peak of the curve as the basal kernels approach the others in total length. By the fourth day kernels 8, 9, and 10 are no longer prominent, and on the fifth day the curve is extremely regular. By the eighth day the length growth is complete and the longest kernels are the fifth and sixth. The curve of the eighth is thought to be more typical than that of the seventh.

The data for the lateral diameter are shown in the same way in figure 7. The same progress of size from the eighth, ninth, and tenth kernels toward the base is to be seen as was found in the length. Here also, the fifth and sixth kernels have exceeded the upper ones by the eighth day

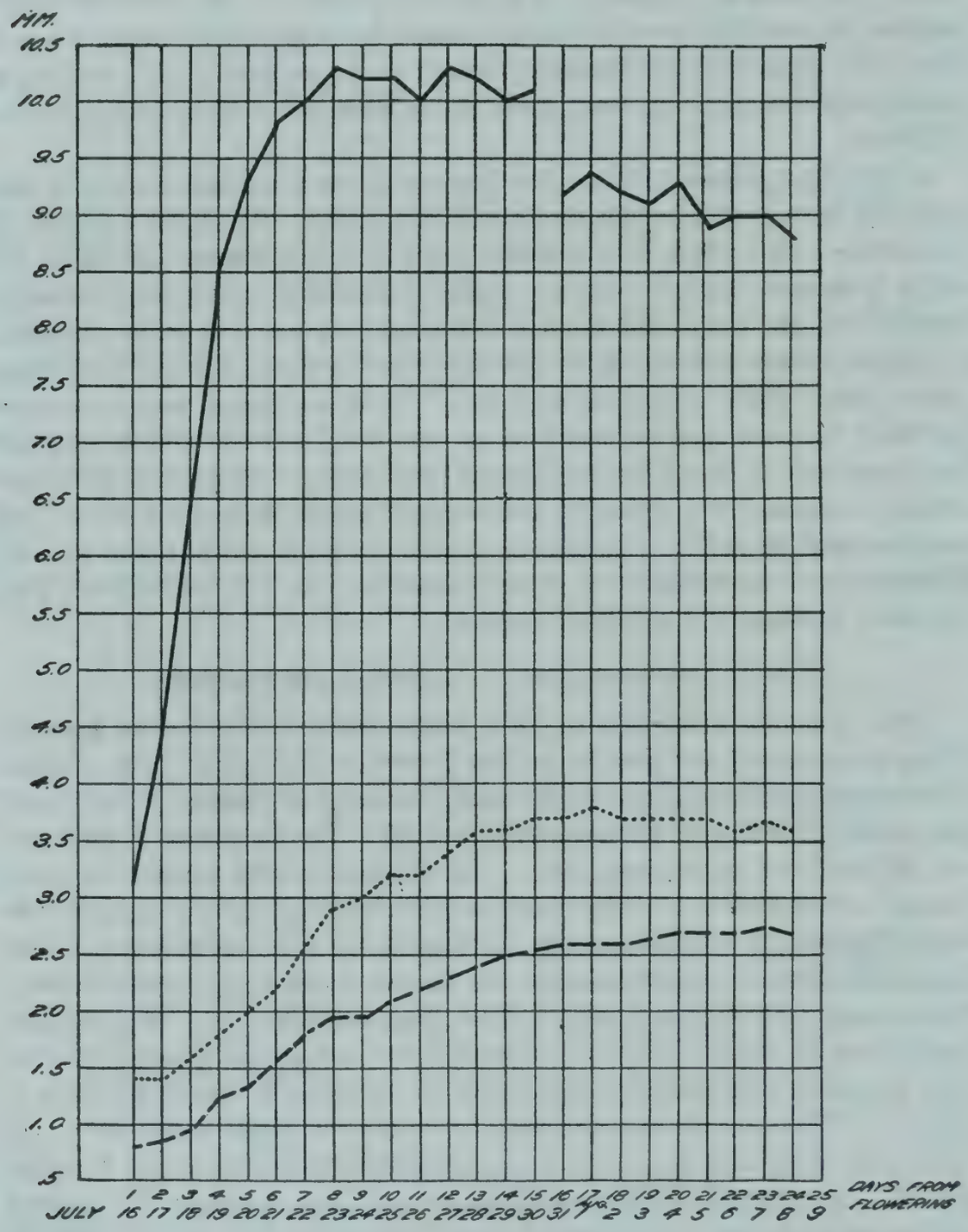

FIG. 5.—Graph showing average length of kernels 6, 7, and 8 (solid line), average lateral diameter (dotted line), and average dorsoventral diameter (broken line) from plot 1 in 1917.

after flowering. The growth in lateral diameter has been practically completed by the sixteenth day. The measurements after the tenth day are given only on alternate days, because the daily increase is so small that the inclusion of all days causes the lines to become confused.

The dorsoventral diameter continues to increase for a longer period. As may be seen in figure 8, the full growth is attained on the twenty-third day after flowering. The greatest diameters in the early growth

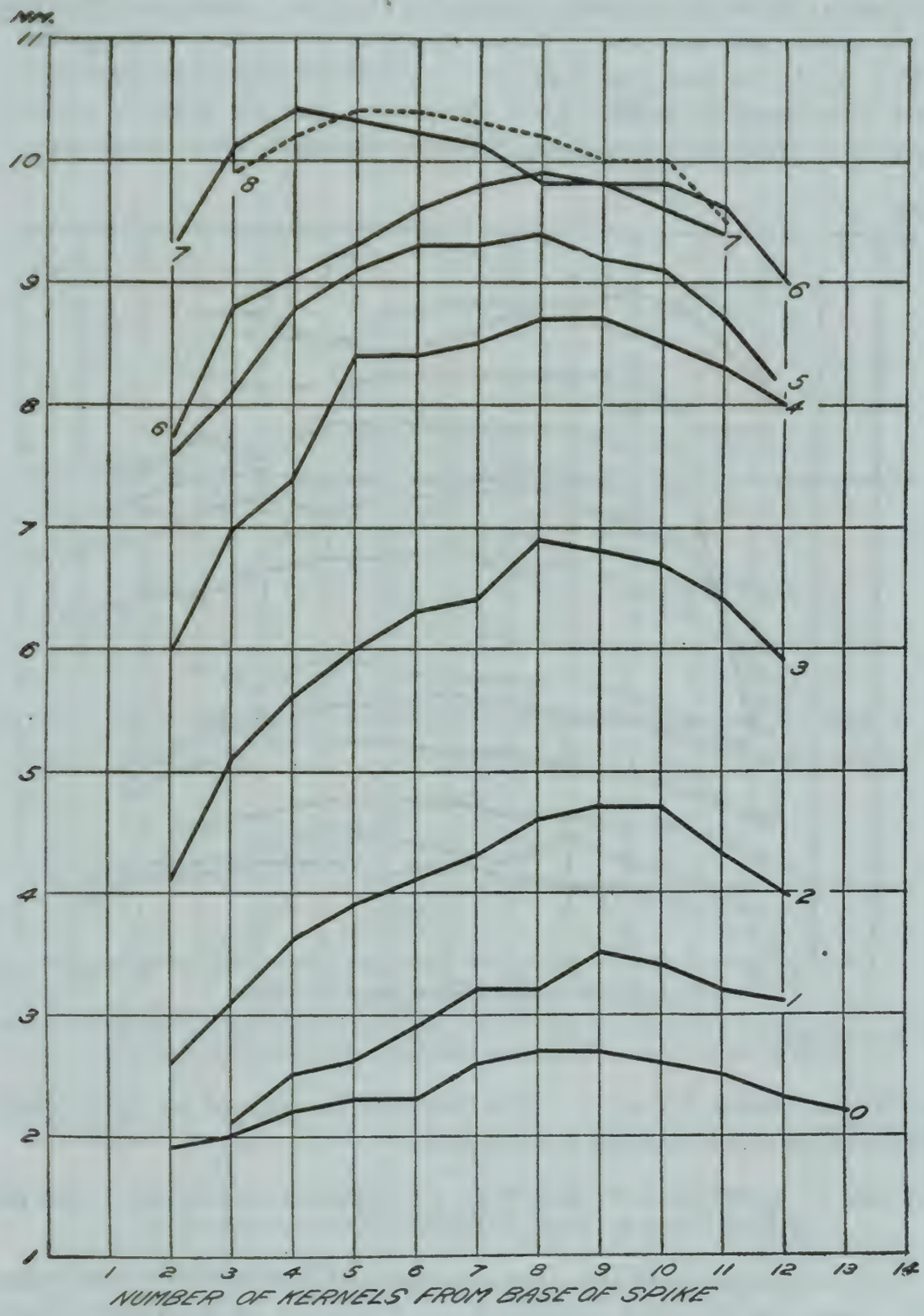

FIG. 6.—Graph showing average length of barley kernels, including ovary tip, from flowering to near maximum development in plot 1 in 1917. Numerals at ends of lines indicate days from flowering.

are to be found in kernels 8, 9, and 10, as was the case in the length and in the lateral diameter. On the fourth, fifth, and sixth days after flowering these kernels are conspicuously in advance of the rest of the spike.

Again, as in the length and the lateral diameter, the kernels toward the base increase more rapidly. The fourth kernel never becomes as prominent as it does in the other measurements. After the growth in length and lateral diameter has been completed, there is a tendency toward a greater permanent increase in the kernels near the center of the spike.

As a whole, the progress of kernel growth is significantly indicated by these three measurements. After the peak is reached there is a slight decrease as maturity approaches. This is especially true in the length

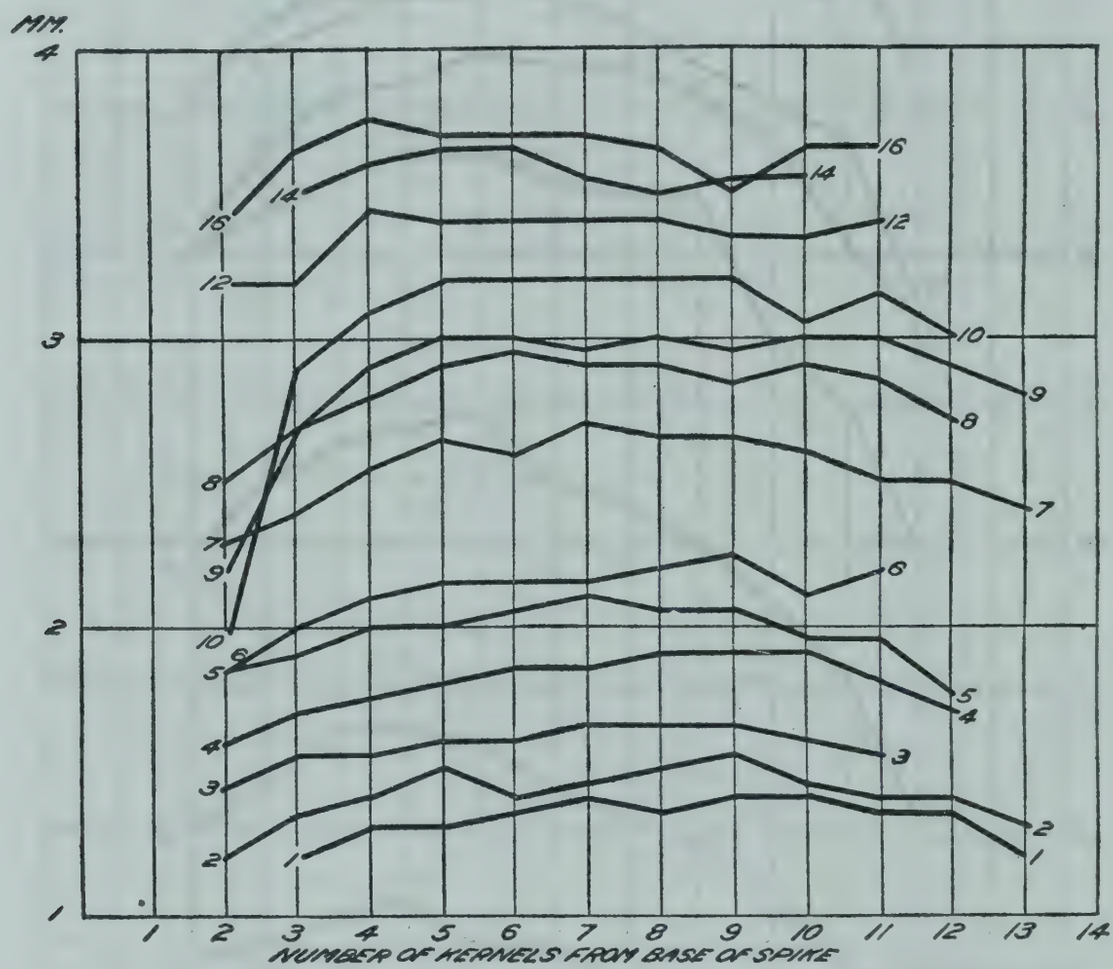

FIG. 7.—Graph showing average lateral diameter of barley kernels from flowering until near maximum development, plot 1, 1917. Numerals at end of lines indicate days from flowering.

and in the lateral diameter. This fact will be referred to again when the course of water content is discussed.

COURSE BY DAYS OF DRY MATTER, WATER, NITROGEN, AND ASH IN THE KERNEL FROM FLOWERING TO MATURITY

The chemical phase of the study is based on the laboratory determinations made on the same samples from which the measurements were secured. In 1916 the material was analyzed by Mr. Anthony. The analyses in 1917 were made by the Bureau of Chemistry of the United States Department of Agriculture. While the chemical investigations involved no such elaborate determinations as those of Schjerning, the results are parallel with those from his work and that of Wheldale.

Table III is a summary of the results obtained and computed on each spike of each sample for 1917. In each sample the material from one spike was used for nitrogen determinations and the material from the

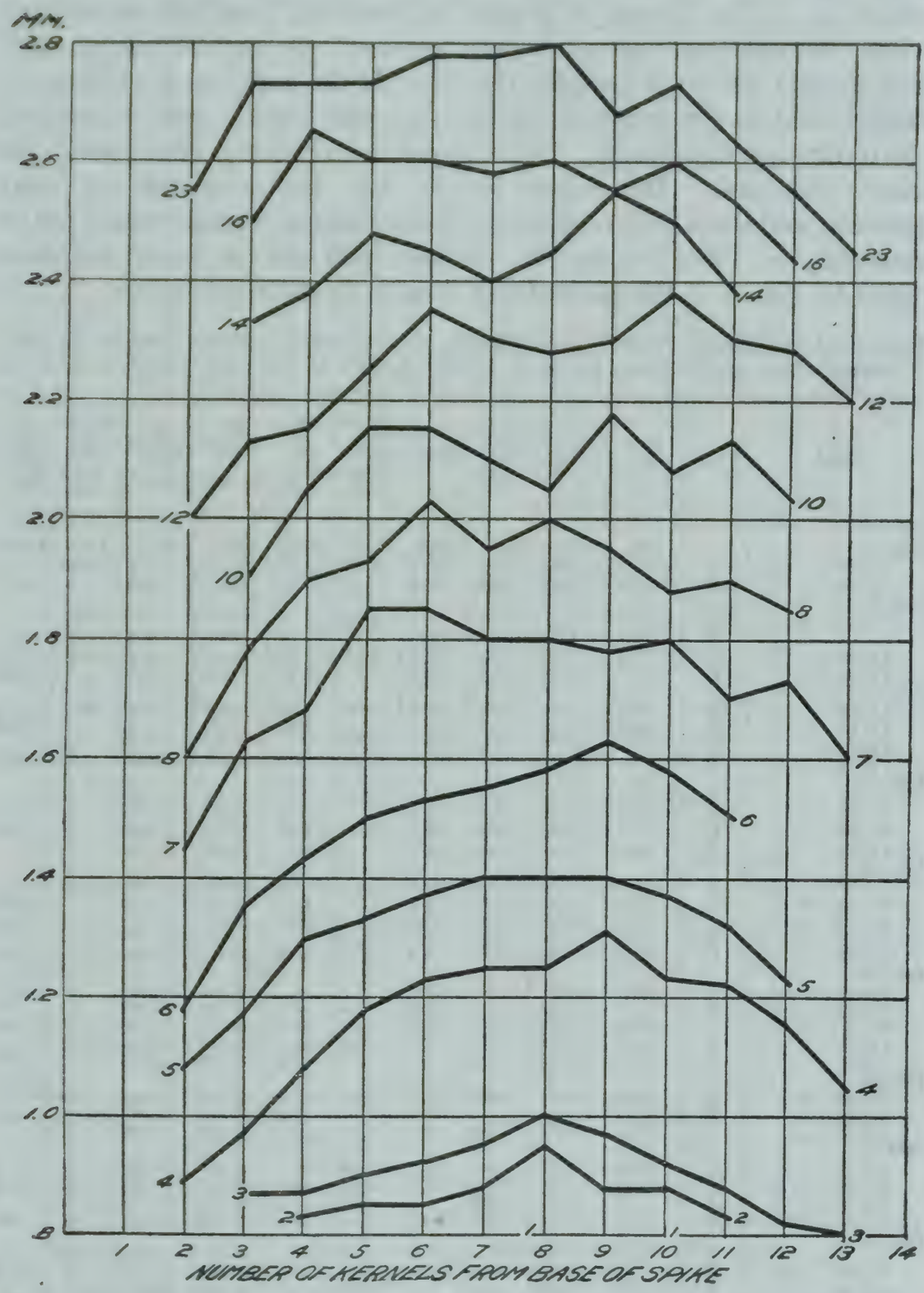

FIG. 8.—Graph showing dorsoventral diameters of barley kernels from flowering until near maximum development. Numerals at ends of lines indicate days from flowering.

other for ash determinations. In the early growth a third spike was sometimes added, but these third spikes are not in the summary, since they were not reported in Table I. Because of the limited amount of

material, the analyses are not always dependable. This is true especially for the first few days after flowering. As may be seen from the table, the weight of the individual kernels was greater at maturity than the weight of all the kernels of a spike at flowering time. In some cases where the analyses were obviously incorrect, the results are omitted. But, despite the small samples, the trend of the analyses is surprisingly uniform and, as the results of the two years are in such close agreement, the results are significant. The nitrogen determination is naturally the least dependable. The results in the ash determinations are more accurate, and there is no reason why the dry matter content should not be absolutely so. The dry weight, nitrogen, and ash per kernel are computed by means of the percentages secured in the whole spike.

TABLE III.—*Summary of data on weight, dry matter, water, nitrogen, and ash in individual spikes of Hannchen barley in 12-hour periods at Aberdeen, Idaho, in 1917*

Time.	Spike.	Wet weight.	Dry weight.	Dry matter.	Water.	Nitrogen in dry matter.	Ash in dry matter.	Wet weight per kernel.	Dry weight per kernel.	Nitrogen per kernel.	Ash per kernel.
July 15:		*Gm.*	*Gm.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*
7 p. m.	A	0.0441	0.0064	14.5	85.5	3.75	.....	1.875	0.272	0.010	.....
7 p. m.	B	.0494	.0085	17.2	82.8	.....	.....	1.862	.320	.....	.....
July 16:											
6 a. m.	A	.0578	.0093	16.1	83.9	4.19	.....	2.275	.366	.015	.....
6 a. m.	B	.0657	.0084	12.8	87.2	.....	.....	2.650	.339	.....	.....
7 p. m.	A	.0745	.0126	16.9	83.1	4.45	.....	3.400	.575	.026	.....
7 p. m.	B	.0778	.0139	17.9	82.1	.....	7.91	3.550	.635	.....	0.050
July 17:											
6 a. m.	A	.0807	.0149	18.5	81.5	3.00	.....	3.050	.564	.017	.....
6 a. m.	B	.0795	.0145	18.2	81.8	.....	8.96	3.400	.619	.....	.056
7 p. m.	A	.1360	.0270	19.9	80.1	3.11	.....	5.909	1.176	.037	.....
7 p. m.	B	.1395	.0273	19.6	80.4	.....	5.86	5.592	1.096	.....	.064
July 18:											
6 a. m.	A	.1767	.0341	19.3	80.7	.....	.....	8.500	1.641	.....	.....
6 a. m.	B	.1477	.0274	18.6	81.4	.....	6.57	6.418	1.194	.....	.078
6 a. m.	C	.1964	.0385	19.6	80.4	.....	5.71	7.650	1.499	.....	.086
7 p. m.	A	.1940	.0406	20.9	79.1	.....	.....	8.391	1.754	.....	.....
July 19:											
6 a. m.	A	.2652	.0540	20.4	79.6	.....	.....	10.883	2.220	.....	.....
6 a. m.	B	.2940	.0637	21.7	78.3	.....	3.77	12.327	2.675	.....	.101
6 a. m.	C	.2389	.0516	21.6	78.4	.....	4.26	11.590	2.503	.....	.107
7 p. m.	A	.2829	.0651	23.0	77.0	.....	.....	14.720	3.386	.....	.....
7 p. m.	C	.2744	.0619	22.6	77.4	.....	4.20	13.027	2.944	.....	.124
July 20:											
6 a. m.	A	.3216	.0723	22.5	77.5	.....	.....	14.672	3.301	.....	.....
6 a. m.	B	.3508	.0798	22.7	77.3	.....	4.51	16.370	3.716	.....	.168
6 a. m.	C	.3863	.0878	22.7	77.3	.....	3.08	16.417	3.727	.....	.115
7 p. m.	A	.3026	.0678	22.4	77.6	2.27	.....	13.900	3.114	.071	.....
7 p. m.	B	.3452	.0756	21.9	78.1	.....	4.63	17.600	3.854	.....	.178
July 21:											
6 a. m.	A	.3356	.0760	22.6	77.4	3.14	.....	16.820	3.801	.119	.....
6 a. m.	B	.3772	.0875	23.2	76.8	.....	3.54	18.560	4.306	.....	.152
7 p. m.	A	.4192	.1060	25.3	74.7	.....	.....	20.655	5.226	.....	.....
July 22:											
6 a. m.	A	.5163	.1328	25.7	74.3	2.33	.....	25.460	6.543	.152	.....
6 a. m.	B	.5996	.1558	26.0	74.0	.....	3.21	26.142	6.797	.....	.218
7 p. m.	A	.5445	.1395	25.6	74.4	2.33	.....	25.555	6.542	.152	.....
7 p. m.	B	.6373	.1635	25.7	74.3	.....	3.79	25.492	6.551	.....	.248
July 23:											
6 a. m.	A	.6429	.1800	28.0	72.0	2.18	.....	32.160	9.005	.196	.....
6 a. m.	B	.5810	.1602	27.6	72.4	.....	4.18	29.630	8.178	.....	.342
7 p. m.	A	.7469	.2194	29.4	70.6	1.95	.....	33.345	9.803	.191	.....
7 p. m.	B	.6699	.1944	29.0	71.0	3.09	3.09	28.891	8.378	.....	.259
July 24:											
6 a. m.	A	.6979	.2150	30.8	69.2	2.08	.....	31.200	9.610	.200	.....
6 a. m.	B	.7856	.2277	29.0	71.0	.....	3.07	31.483	9.130	.....	.280
7 p. m.	A	.6967	.2197	31.5	68.5	2.17	.....	33.720	10.622	.230	.....
7 p. m.	B	.8496	.2741	32.3	67.7	.....	2.77	34.592	11.173	.....	.309
July 25:											
6 a. m.	A	.8208	.2718	33.1	66.9	1.96	.....	37.055	12.265	.240	.....
6 a. m.	B	.8024	.2496	31.1	68.9	.....	2.88	35.482	11.035	.....	.318
7 p. m.	A	.7131	.2618	36.7	63.3	1.92	.....	34.527	12.671	.243	.....
7 p. m.	B	.6832	.2285	33.4	66.6	.....	2.93	37.100	12.391	.....	.363

TABLE III.—*Summary of data on weight, dry matter, water, nitrogen, and ash in individual spikes of Hannchen barley in 12-hour periods at Aberdeen, Idaho, in 1917*—Continued

Time.	Spike.	Wet weight.	Dry weight.	Dry matter.	Water.	Nitrogen in dry matter.	Ash in dry matter.	Wet weight per kernel.	Dry weight per kernel.	Nitrogen per kernel.	Ash per kernel.
July 26:		*Gm.*	*Gm.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*
6 a. m.	A	0.7677	0.2608	34.0	66.0	2.04	.....	36.640	12.458	0.254	.....
6 a. m.	B	.7302	.2630	36.0	64.0	.....	2.62	36.660	13.198	.....	0.346
7 p. m.	A	.7955	.3000	37.7	62.3	1.87	.....	39.860	15.027	.281	.....
7 p. m.	B	.8527	.3164	37.1	62.9	.....	2.72	39.682	14.722	.....	.400
July 27:											
6 a. m.	A	1.0141	.3712	36.6	63.4	2.04	.....	43.200	15.811	.323	.....
6 a. m.	B	.9320	.3405	36.5	63.5	.....	2.61	45.364	16.558	.....	.432
7 p. m.	A	1.1596	.4435	38.2	61.8	2.02	.....	44.731	17.087	.345	.....
7 p. m.	B	.8451	.3205	37.9	62.1	.....	2.84	45.130	17.104	.....	.486
July 28:											
6 a. m.	A	1.1301	.4025	35.6	64.4	2.09	.....	45.550	16.216	.339	.....
6 a. m.	B	1.2476	.4902	39.3	60.7	.....	2.41	49.300	19.375	.....	.467
7 p. m.	A	1.0862	.4515	41.6	58.4	1.86	.....	48.991	20.380	.379	.....
7 p. m.	B	1.1338	.4674	41.2	58.8	.....	2.42	48.775	20.095	.....	.486
July 29:											
6 a. m.	A	.9978	.4061	40.7	59.3	1.86	.....	49.570	20.175	.375	.....
6 a. m.	B	.9214	.3614	39.2	60.8	.....	2.49	47.180	18.495	.....	.461
7 p. m.	A	.9233	.3847	41.7	58.3	2.19	.....	49.590	20.679	.453	.....
7 p. m.	B	.9841	.4237	43.1	56.9	.....	2.43	49.540	21.352	.....	.519
July 30:											
6 a. m.	A	.9350	.4015	42.9	57.1	2.02	.....	52.811	22.656	.458	.....
6 a. m.	B	1.1415	.4725	41.4	58.6	.....	2.10	50.091	20.738	.....	.435
7 p. m.	A	1.3826	.6008	43.5	56.5	2.00	.....	56.708	24.668	.493	.....
7 p. m.	B	1.0599	.4701	44.4	55.6	.....	2.28	52.320	23.230	.....	.530
July 31:											
6 a. m.	A	1.1090	.4837	43.6	56.4	2.09	.....	50.600	22.062	.461	.....
6 a. m.	B	1.3637	.6065	44.5	55.5	.....	2.41	52.777	23.486	.....	.566
6.30 p. m.	A	1.1058	.5098	46.1	53.9	2.14	.....	55.580	25.622	.548	.....
6.30 p. m.	B	1.0597	.5038	47.5	52.5	.....	2.22	49.909	23.707	.....	.526
August 1:											
6 a. m.	A	1.3393	.6261	46.7	53.3	1.89	.....	53.862	25.154	.475	.....
6 a. m.	B	1.2231	.5814	47.5	52.5	.....	2.27	56.264	26.725	.....	.607
6.30 p. m.	A	1.2283	.5928	48.3	51.7	2.08	.....	54.973	26.552	.552	.....
6.30 p. m.	B	1.2051	.6012	49.9	50.1	.....	2.25	53.933	26.913	.....	.606
August 2:											
6 a. m.	A	1.2996	.6071	46.8	53.2	1.82	.....	54.508	25.510	.464	.....
6 a. m.	B	1.2460	.5969	47.9	52.1	.....	1.94	56.609	27.116	.....	.526
6.30 p. m.	A	.9942	.4974	50.0	50.0	1.97	.....	50.860	25.430	.501	.....
6.30 p. m.	B	.9693	.4818	49.7	50.3	.....	2.12	51.027	25.300	.....	.538
August 3:											
6 a. m.	A	1.3453	.6846	50.9	49.1	1.85	.....	54.062	27.518	.509	.....
6 a. m.	B	1.1579	.5711	49.3	50.7	.....	2.10	56.200	27.707	.....	.582
6.45 p. m.	A	1.3575	.6850	50.5	49.5	2.04	.....	61.309	30.961	.632	.....
6.45 p. m.	B	1.0280	.5161	50.2	49.8	.....	2.00	51.670	25.938	.....	.519
August 4:											
5.45 a. m.	A	1.0870	.5380	49.5	50.5	1.85	.....	53.236	26.352	.488	.....
5.45 a. m.	B	1.1618	.5690	49.0	51.0	.....	1.97	55.836	27.360	.....	.539
6.45 p. m.	A	1.3289	.6795	51.1	48.9	2.18	.....	56.175	28.705	.626	.....
6.45 p. m.	B	1.5152	.8077	53.3	46.7	.....	1.97	59.777	31.861	.....	.628
August 5:											
6 a. m.	A	1.1586	.5882	50.8	49.2	1.86	.....	60.322	30.644	.570	.....
6 a. m.	B	.9911	.5175	52.2	47.8	.....	1.93	53.220	27.781	.....	.536
6.30 p. m.	A	1.3447	.7412	55.1	44.9	1.91	.....	54.817	30.204	.577	.....
6.30 p. m.	B	1.1509	.6146	53.4	46.6	.....	1.94	55.320	29.541	.....	.573
August 6:											
6 a. m.	A	1.3166	.6978	53.0	47.0	2.03	.....	60.909	32.282	.655	.....
6 a. m.	B	1.2923	.6779	52.5	47.5	.....	1.83	57.118	29.987	.....	.549
6.40 p. m.	A	1.3166	.7470	56.7	43.3	1.97	.....	56.991	32.314	.637	.....
6.40 p. m.	B	1.0200	.5907	57.9	42.1	.....	1.95	51.480	29.807	.....	.581
August 7:											
6 a. m.	A	1.5329	.8254	53.8	46.2	2.27	.....	61.608	33.145	.752	.....
6 a. m.	B	1.2783	.7104	55.6	44.4	.....	1.93	59.127	32.875	.....	.634
7 p. m.	A	1.0927	.6367	58.3	41.7	.....	.....	54.964	32.044	.....	.....
7 p. m.	B	1.3414	.7723	57.6	42.4	.....	1.93	56.342	32.453	.....	.626
August 8:											
6 a. m.	A	1.4838	.8217	55.4	44.6	2.28	.....	58.923	32.643	.744	.....
6 a. m.	B	1.3004	.7457	57.3	42.7	.....	1.98	58.573	33.562	.....	.665
6.40 p. m.	A	1.0100	.5903	58.4	41.6	.....	.....	53.633	31.322	.....	.....
6.40 p. m.	B	1.0614	.6083	57.3	42.7	.....	1.77	53.310	30.547	.....	.541

The material in Table III is summarized in Table IV. In the first part of Table IV the spikes of each sample are combined so as to give the average growth in 12-hour periods. In the second part of the table the

morning and evening averages are united to give the average growth in 24-hour periods. While many points of interest are perfectly apparent in the table, it is more convenient to discuss these data under the headings of the separate constituents, where the results are represented graphically.

TABLE IV.—*Average percentage of dry matter and water per kernel in Hannchen barley, percentage of nitrogen and ash in dry matter, and actual total weight, weight of dry matter, water, nitrogen, and ash at 12-hour and 24-hour periods at Aberdeen, Idaho, in 1917*

12-HOUR PERIODS

Time.	Dry matter.	Water.	Nitrogen in dry matter.	Ash in dry matter.	Wet weight.	Dry matter.	Water.	Nitrogen.	Ash.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*
July 15, p. m.	15.9	84.1	3.75	.....	1.9	0.3	1.6	0.01	.....
16, a. m.	14.5	85.5	4.19	.....	2.5	.4	2.1	.02	.....
16, p. m.	17.4	82.6	4.45	7.91	3.5	.6	2.9	.03	0.05
17, a. m.	18.4	81.6	3.00	8.96	3.2	.6	2.6	.02	.05
17, p. m.	19.8	80.2	3.11	5.86	5.8	1.1	4.6	.04	.07
18, a. m.	19.2	80.8	.....	6.14	7.5	1.4	6.1	.....	.09
18, p. m.	20.9	79.1	.....	.....	8.4	1.8	6.6	.....	.....
19, a. m.	21.2	78.8	.....	4.02	11.6	2.5	9.1	.....	.10
19, p. m.	22.8	77.2	.....	4.20	13.9	3.2	10.7	.....	.13
20, a. m.	22.6	77.4	.....	3.80	15.8	3.6	12.2	.....	.14
20, p. m.	22.2	77.8	2.27	4.63	15.8	3.5	12.3	.08	.16
21, a. m.	22.9	77.1	3.14	3.54	17.7	4.1	13.6	.13	.14
21, p. m.	25.3	74.7	.....	.....	20.7	5.2	15.4	.....	.....
22, a. m.	25.9	74.1	2.33	3.21	25.8	6.7	19.1	.16	.21
22, p. m.	25.7	74.3	2.33	3.79	25.5	6.5	19.0	.15	.25
23, a. m.	27.6	72.2	2.18	4.18	30.9	8.6	22.3	.19	.36
23, p. m.	29.2	70.8	1.95	3.09	31.1	9.1	22.0	.18	.28
24, a. m.	29.9	70.1	2.08	3.07	31.3	9.4	22.0	.20	.29
24, p. m.	31.9	68.1	2.17	2.77	34.2	10.9	23.3	.24	.30
25, a. m.	32.1	67.9	1.96	2.88	36.3	11.7	24.6	.23	.34
25, p. m.	35.1	64.9	1.92	2.93	35.8	12.5	23.3	.24	.37
26, a. m.	35.0	65.0	2.04	2.62	36.7	12.8	23.8	.26	.34
26, p. m.	37.4	62.6	1.87	2.72	39.8	14.9	24.9	.28	.41
27, a. m.	36.6	63.4	2.04	2.61	44.3	16.2	28.1	.33	.42
27, p. m.	38.1	61.9	2.02	2.84	44.9	17.1	27.8	.35	.49
28, a. m.	37.5	62.5	2.09	2.41	47.4	17.8	29.6	.37	.43
28, p. m.	41.4	58.6	1.86	2.42	48.9	20.2	28.6	.38	.49
29, a. m.	40.0	60.0	1.86	2.49	48.4	19.3	29.0	.36	.48
29, p. m.	42.4	57.6	2.19	2.43	49.6	21.0	28.5	.46	.51
30, a. m.	42.2	57.8	2.02	2.10	51.5	21.7	29.8	.44	.46
30, p. m.	45.0	55.0	2.00	2.28	54.5	23.9	30.6	.48	.55
31, a. m.	44.1	55.9	2.09	2.41	51.7	22.8	28.9	.48	.55
31, p. m.	46.8	53.2	2.14	2.22	52.7	24.7	28.1	.53	.55
Aug. 1, a. m.	47.1	52.9	1.89	2.27	55.1	25.9	29.1	.49	.59
1, p. m.	49.1	50.9	2.08	2.25	54.5	26.7	27.7	.56	.60
2, a. m.	47.4	52.6	1.82	1.94	55.9	26.3	29.2	.48	.51
2, p. m.	49.9	50.1	1.97	2.12	50.9	25.4	25.5	.50	.54
3, a. m.	50.1	49.9	1.85	2.10	55.1	27.6	27.5	.51	.58
3, p. m.	50.4	49.6	2.04	2.00	56.5	28.5	28.0	.58	.57
4, a. m.	49.3	50.7	1.85	1.97	54.5	26.9	27.7	.50	.53
4, p. m.	52.2	47.8	2.18	1.97	58.0	30.3	27.7	.66	.60
5, a. m.	51.5	48.5	1.86	1.93	56.8	29.2	27.6	.54	.56
5, p. m.	54.3	45.7	1.91	1.94	55.1	29.9	25.1	.57	.58
6, a. m.	52.8	47.2	2.03	1.83	59.0	31.1	27.9	.63	.57
6, p. m.	57.3	42.7	1.97	1.95	54.2	31.1	23.1	.61	.61
7, a. m.	54.7	45.3	2.27	1.93	60.4	33.0	27.4	.75	.64
7, p. m.	58.0	42.0	.....	1.93	55.7	32.3	23.4	.....	.62
8, a. m.	56.4	43.6	2.28	1.98	59.0	33.1	25.6	.76	.66
8, p. m.	57.9	42.1	.....	1.77	53.4	30.9	22.5	.....	.55

TABLE IV.—*Average percentage of dry matter and water per kernel in Hannchen barley, percentage of nitrogen and ash in dry matter, and actual total weight, weight of dry matter, water, nitrogen, and ash in 12-hour and 24-hour periods at Aberdeen, Idaho, in 1917*—Continued

24-HOUR PERIODS

Time.	Dry matter.	Water.	Nitrogen in dry matter.	Ash in dry matter.	Wet weight.	Dry matter.	Water.	Nitrogen.	Ash.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*
July 15	15.9	84.1	3.75	.....	1.9	0.3	1.6	0.01	.....
16	16.0	84.0	4.32	7.91	3.0	.5	2.5	.02	0.05
17	19.1	80.9	3.06	7.41	4.5	.9	3.6	.03	.06
18	20.1	79.9	.....	6.14	8.0	1.6	6.4	.....	.09
19	22.0	78.0	.....	4.11	12.7	2.8	9.9	.....	.12
20	22.4	77.6	2.27	4.22	15.8	3.5	12.3	.08	.15
21	24.1	75.9	3.14	3.54	19.2	4.6	14.5	.13	.14
22	25.8	74.2	2.33	3.50	25.7	6.6	19.1	.15	.23
23	28.5	71.5	2.07	3.64	31.0	8.8	22.2	.18	.32
24	30.9	69.1	2.13	2.92	32.7	10.1	22.6	.22	.30
25	33.6	66.4	1.94	2.91	36.0	12.1	24.0	.23	.35
26	36.2	63.8	1.96	2.67	38.2	13.9	24.4	.27	.37
27	37.4	62.6	2.03	2.73	44.6	16.6	28.0	.34	.45
28	39.5	60.5	1.98	2.42	48.2	19.0	29.1	.37	.46
29	41.2	58.8	2.03	2.46	49.0	20.2	28.8	.41	.50
30	43.6	56.4	2.01	2.19	53.0	22.8	30.2	.46	.50
31	45.5	54.5	2.12	2.32	52.2	23.7	28.5	.50	.55
Aug. 1	48.1	51.9	1.99	2.26	54.8	26.3	28.4	.52	.59
2	48.7	51.3	1.90	2.03	53.3	25.9	27.4	.49	.52
3	50.3	49.7	1.95	2.05	55.8	28.1	27.8	.55	.58
4	50.8	49.2	2.02	1.97	56.3	28.6	27.7	.58	.56
5	52.9	47.1	1.89	1.94	55.9	29.5	26.4	.56	.57
6	55.1	44.9	2.00	1.89	56.6	31.1	25.5	.62	.59
7	56.4	43.6	2.27	1.93	58.0	32.6	25.4	.75	.63
8	57.2	42.8	2.28	1.88	56.1	32.0	24.1	.76	.60

CHANGES IN WET WEIGHT PER KERNEL

The trend of the wet weight is indicated in Table III and is summarized in Table IV. The course of development is more apparent in figure 9, where the growth of kernels 5, 8, and 10 is represented graphically. The most rapid increase occurs in the first 16 days. After this time the loss of water is almost equal to the increase in dry matter. The fifth, eighth, and tenth kernels represent different sections of the spike. The order of weight is reversed during the period of growth. The tenth kernel was the first of the three to be fertilized, and it reaches a constant weight some time before the fifth kernel does.

The shift of wet weight is much more evident in figure 10, where the weights of all kernels are shown. The trend of development in the wet weight is quite parallel to that of the length, lateral diameter, and dorsoventral diameter shown in figures 6, 7, and 8. The shift here proceeds toward the base until the fourth kernel is the heaviest, and it is only toward the last that the fifth and sixth kernels become the highest in weight. The wet weight, owing to the difference of moisture content

between the kernels at the base of the spike and those at the tip, is not an accurate indication of the storage of nutrient material. The curve of wet weight is quite similar to that published by Brenchley (*1*). The losses after maturity found by Brenchley were not evident at Aberdeen, because the sampling was not carried to the same point. Brenchley included the glumes in the weights, while at Aberdeen these were removed. As the glumes can not be removed after maturity, their removal shortens the period of study. On the other hand, the glumes themselves change

FIG. 9.—Graph showing wet weight of individual kernels 5, 8, and 10, by days, from date of flowering to near maturity in 1917.

materially in character between flowering and maturity, and their elimination removes one source of error.

INCREASE IN DRY MATTER

The daily growth of the kernel is summarized in the daily increment of dry matter. While there are gradual changes in the percentages of the various substances for days of the same week, the added constituents bear a more or less uniform relation to each other. The sum of the daily additions is the increase in dry matter. This increase has been so uniform at Aberdeen as to indicate that the plants were working very nearly at

their highest capacity. In figure 11 are given the dry-matter contents of kernels in 1916 and 1917. For the first 17 days after flowering the curves of the two years practically coincide. After the seventeenth day the rate of deposit decreases in 1917 but is maintained for several days in 1916. This is due, probably, to lack of sufficient water after this date in 1917, the effect of which is noticeable in all the results reported. The gain is surprisingly uniform for the most part. In each season, the curve is essentially a straight line from the sixth until the eighteenth

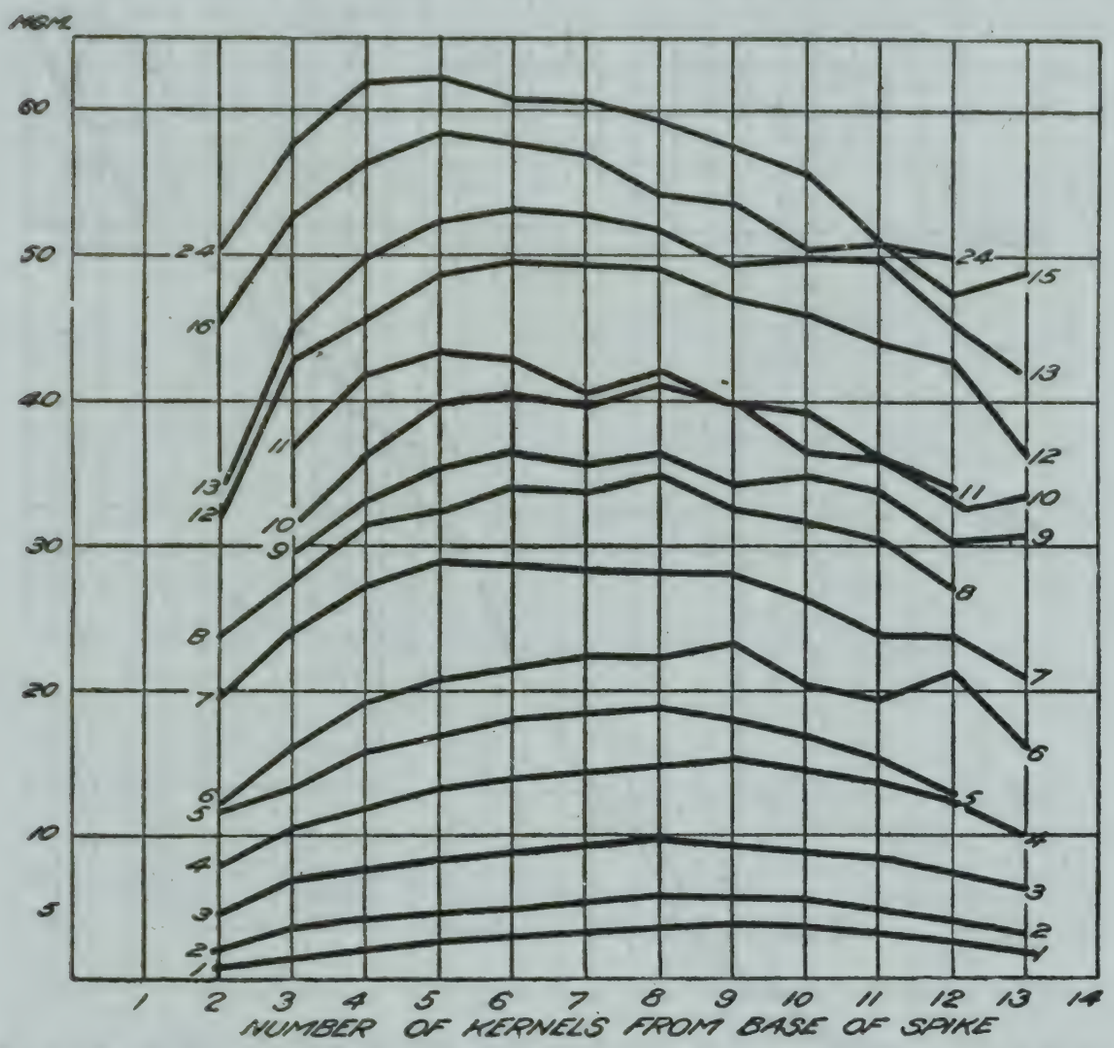

FIG. 10.—Graph showing average wet weights of kernels from flowering to maturity in plot 1 in 1917. Numerals at ends of lines indicate days from flowering.

day. This is interesting in its relation to the general laws of plant growth. In a developing plant, where the new tissue added becomes immediately productive of nutrient material for growth, the increase is accelerated in geometrical ratio. The curve of growth, in this case, can be reduced to a straight line in plotting by the use of logarithmic paper. In the case of kernel growth, by the fourth or fifth day after flowering, the maximum leaf and sheath surface is exposed. The plant food metabolized is diverted to the storage tissues of the kernel, and, since the productive tissues remain constant in amount, the curve of kernel growth is a straight line.

The uniformity of the Aberdeen seasons and the accuracy of the method of sampling used is nowhere more evident than in figure 12. In this figure the dry matter per kernel is plotted in 12-hour periods. For the first 14 days neither the error of sampling nor the differences in rate of growth of individual spikes, separately or together, exceeds the growth

FIG. 11.—Graph showing dry matter per kernel from date of flowering to near maturity in 1916 (dotted line) and in 1917 (solid line).

in 12 hours. There is an apparent reversal of the curve in the fifth and seventh days after flowering, but the larger of these losses is less than 0.2 mgm., and in each case is due to the abnormalities of a few kernels on the spike. When this curve is plotted from the data of the more representative sixth, seventh, and eighth kernels, these irregularities disappear. It is only when the fourteenth day is reached that fluctuations

become common. After this date results are not consistent in such short periods as 12 hours.

The original purpose of the 12-hour interval was to discover, if possible, whether or not growth occurred during the night. For this reason, the periods are not quite equal. The day period consisted of about 13 hours at the beginning. As the days grew shorter this was reduced slightly. This period was thought to include the hours of effective sunlight. In figure 13 the gains and losses for the day and night periods are indicated graphically. The disadvantage of such presentation lies in the magnification of the fluctuations. For instance, the night sample of July 26 shows a decrease of 120 points, not because it is smaller than the sample of July

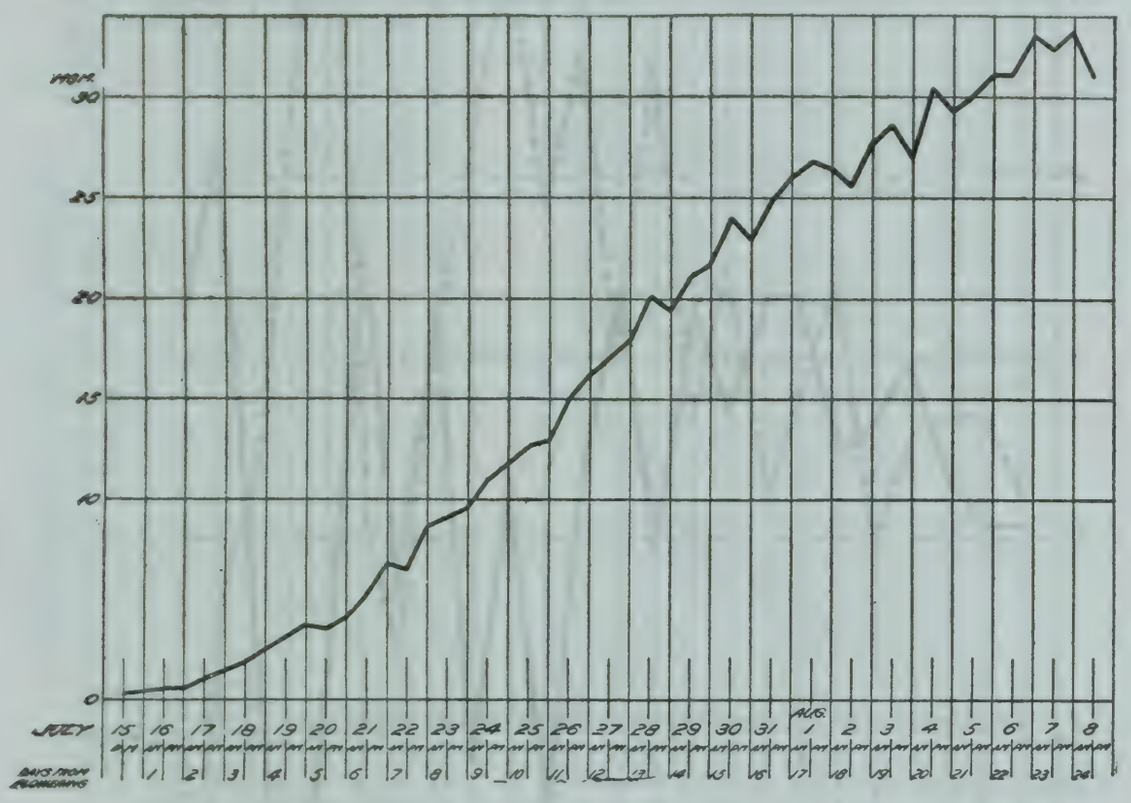

FIG. 12.—Graph showing dry matter per kernel at 12-hour intervals from flowering to maturity.

25, but because it is the same size and, therefore, no gain is registered. For the first 10 days after flowering the day and night gains appear to be nearly equal. From this time until maturity the day gain is obviously greater. The author has no interpretation to suggest, but there are two facts which may be noted. The night gains are most prominent before starch infiltration has become very active. The temperatures, after the first 10 days, are lower, the first night without gain being recorded on July 26, when the mean temperature first falls to 70° F. It is not known whether these facts have any essential relation to the results obtained or not. During the latter part of the growth period, the variation of individual spikes makes the results inconclusive.

The significant features of the data on dry-matter content are (1) the long period of daily gains following the completion of length growth,

which results in a straight line through a considerable portion of the curve when plotted, and (2) the unusual uniformity of increase which permits the taking of samples which show growth in 12-hour periods for two weeks

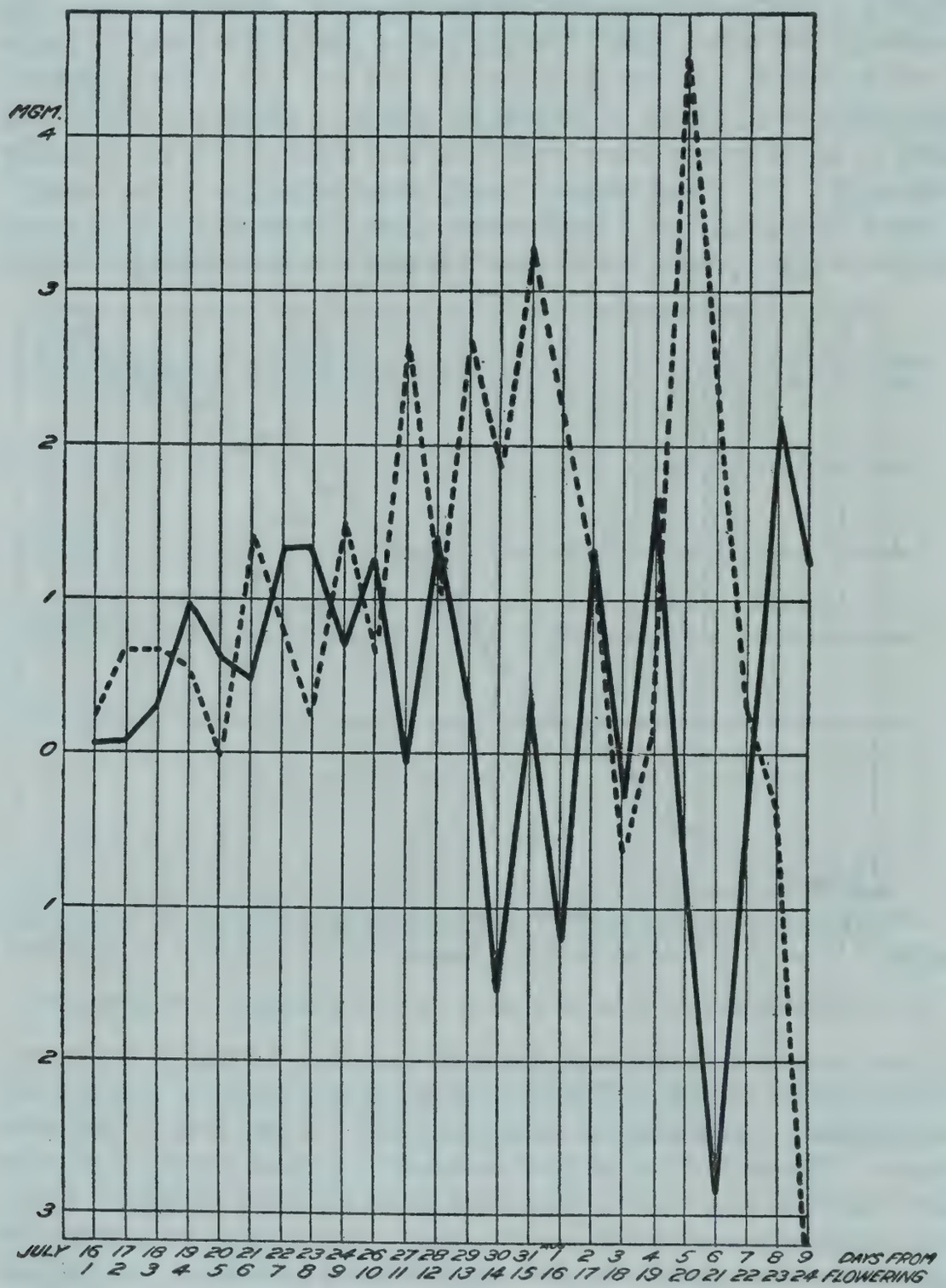

FIG. 13.—Graph showing dry-weight gain of kernels 6, 7, and 8 in 12-hour periods. Gain during the day is shown by the broken line and that during the night by the solid line.

after flowering. The curve of growth as found by Brenchley was quite similar to that shown in figure 11. The same straight line is apparent during the period of rapid starch infiltration, despite the fact that she took samples only every third day. The results seem to agree in a general

way with those of Schjerning, but inasmuch as his samples were less frequently taken, close comparison is not readily made.

CHANGES IN WATER CONTENT

The percentage of water in the kernel is highest at flowering time, when over 80 per cent of the caryopsis is water. From flowering until maturity the percentage of water constantly decreases. At maturity the water content has fallen to about 40 per cent. The decrease in percentage is very uniform, as may be seen in figure 2. The curves of 1916

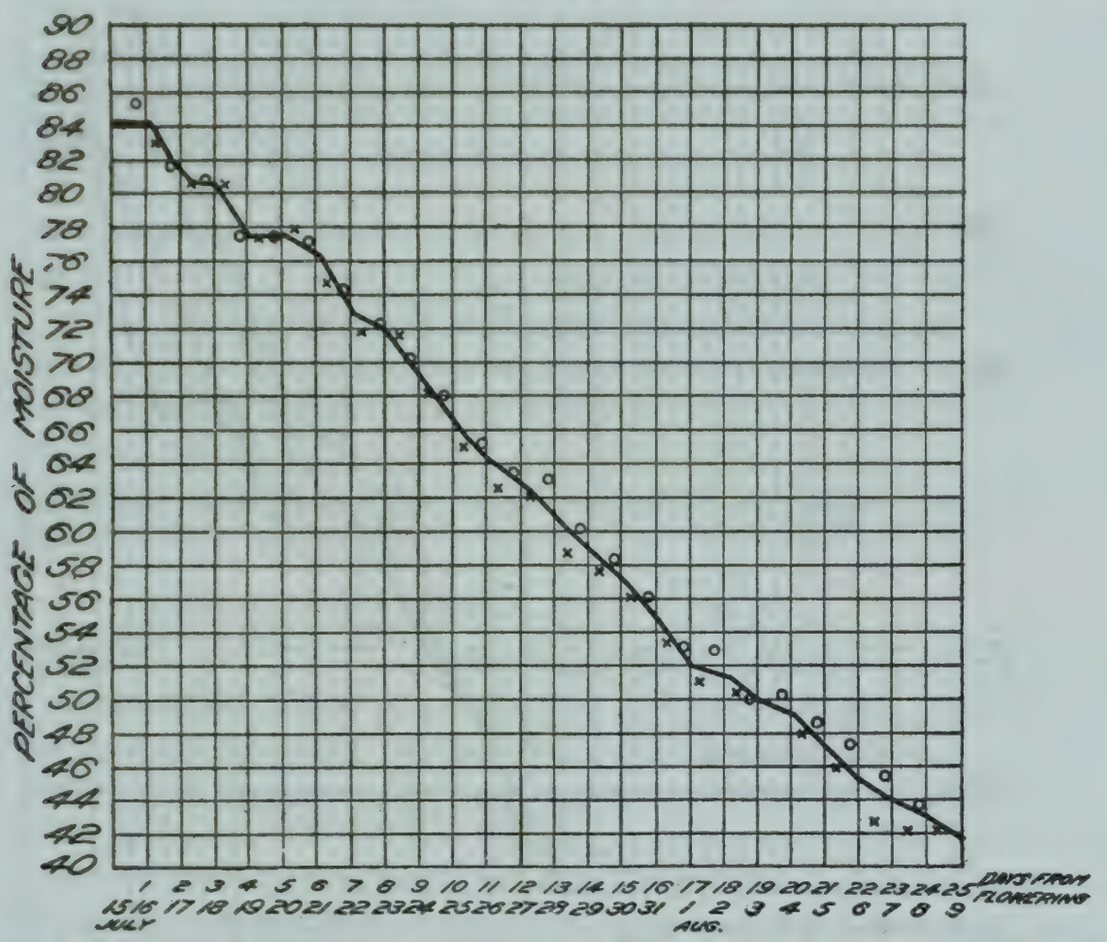

FIG. 14.—Graph showing percentage of moisture in morning and evening samples of Hannchen barley in 1917. The average for the day is indicated by the line. The average morning determinations are indicated by circles, and evening determinations by crosses.

and 1917 are essentially identical. As previously remarked, the coincidence of these curves is evidence of the exceptional opportunity afforded at Aberdeen for comparative studies in development.

The loss of water in percentage is much more rapid than in the results obtained by Brenchley. At Aberdeen the rate is almost 2 per cent a day. At Rothamsted the rate during infiltration was in the neighborhood of 1 per cent a day, although the rate was higher than this at times.

The effect of evaporation during the day was noticeable. The morning sample usually showed a gain in percentage of moisture over that of the night before. The loss of water during the day was rapid, evidently exceeding the normal loss, due to the incident of growth. This extra-normal loss and its recovery are shown in figure 14.

INCREASE IN NITROGEN CONTENT

The nitrogen determinations are the least satisfactory of the studies made. The samples were so small that microchemical methods had to

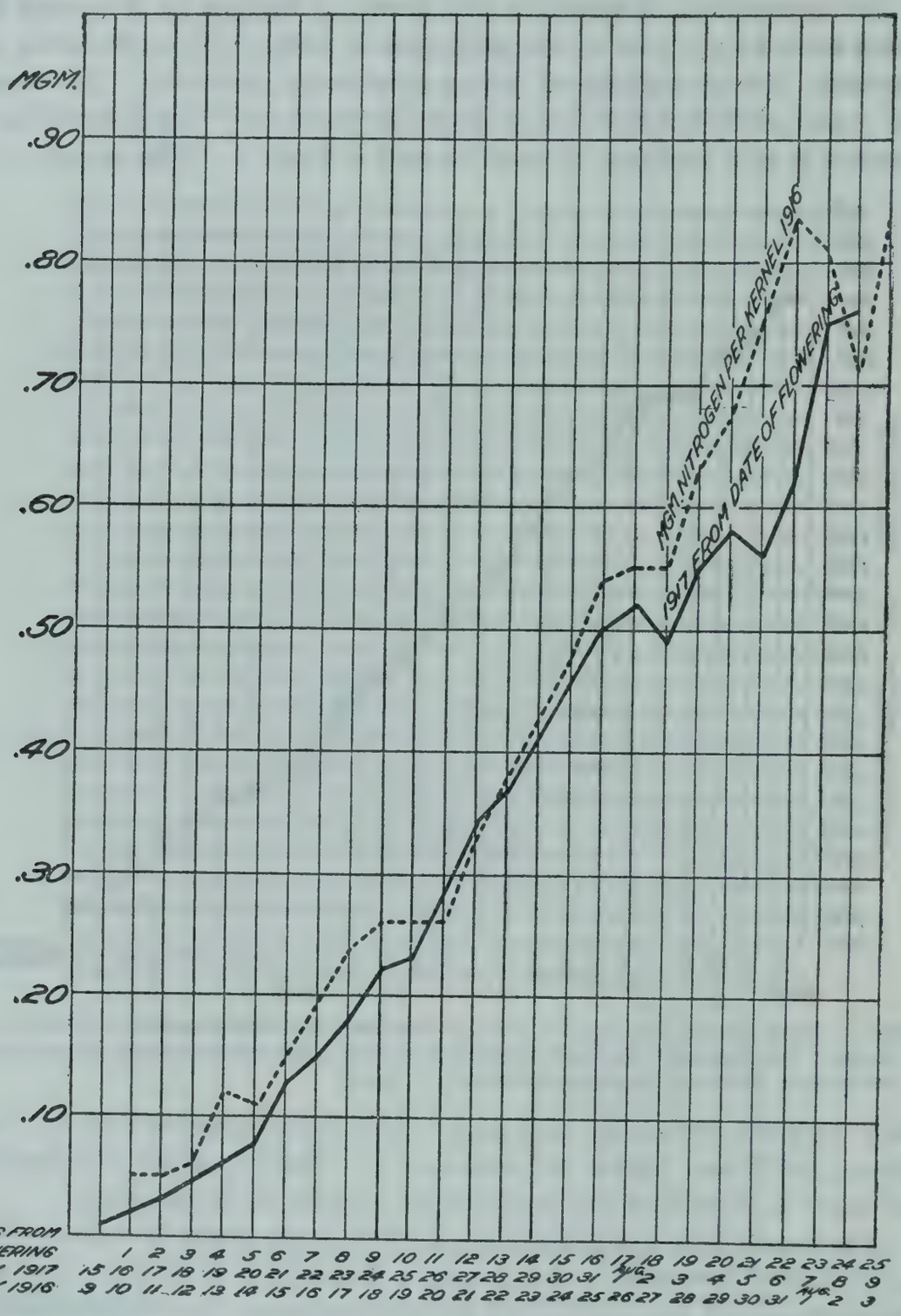

FIG. 15.—Graph showing nitrogen per kernel from date of flowering in 1916 (broken line) and in 1917 (solid line).

be used in the early stages of growth. While the material itself was probably fairly uniform, the determinations are not delicate enough to show a uniform progression in percentage. When the percentages are computed on the dry weight to obtain the milligrams of nitrogen per

grain, the results are much more uniform. In figure 15 is given the total nitrogen per kernel in both 1916 and 1917. The curves are essentially identical. The divergence after the seventeenth day is due to the lesser gain in dry matter after that time in 1917. The divergence in nitrogen content is about the same as in the dry matter shown in figure 11. The results obtained agree very closely with those of Schjerning in Denmark and Brenchley in England.

INCREASE IN ASH

The percentage of ash in the kernel decreases uniformly from flowering to maturity. At the time of fertilization the percentage is high, and for 48 hours after flowering it is more than 7 per cent. The decrease in percentage from that time is not due to loss of ash, as may be seen in figure 16, but to the more rapid increase of other materials. In other experiments, to be reported later, it has been found that the ash content is in fairly close relation to the amount of water available for the use of the plant. The curves of the ash content of 1916 and 1917 again indicate that the irrigation of 1917 was insufficient. The greater growth of 1916 has been mentioned previously; and while a part of it may have been due to better soil in 1916 a part was certainly due to the more generous irrigation of that year, coupled with the fact that the soil used in 1916 absorbed water somewhat more readily than that used in 1917.

PERIODS OF DEVELOPMENT

The Hannchen barley at Aberdeen exhibits a development which is very uniform from year to year. This development, while steadily progressive from flowering to maturity, varies considerably in its nature. The first five days after fertilization are marked by an extremely rapid growth in length. The kernel has reached its maximum in this respect by the seventh day. About the time the growth in length ceases the rapid gain in dry matter begins and continues for about two weeks. Thus the fifth or sixth day marks a change in the character of growth. About the ninth or tenth day a sticky substance is formed in the outer layers of the caryopsis, which causes the glumes to adhere thereafter to the developing kernel. The nature of this substance has not been included in this study, but its origin is evidently in the caryopsis and not in the glumes. This has been demonstrated in the making of hybrids. In this process the upper part of the florets is removed. At maturity the tips of the projecting kernels are often found stuck fast to the paper in which the spike was wrapped. The appearance of this adhesive substance on the ninth or tenth day would seem to mark a second stage of development. Since the inner tissues of the kernel are very soft, it is difficult, from this time until the kernel has somewhat hardened, to remove the glumes without tearing the kernel. This hardening occurs

about the fifteenth or sixteenth day at Aberdeen. It is accompanied by several other phenomena as well. The lemma begins to lose its color in the center of the dorsal surface. The awns of the Hannchen variety,

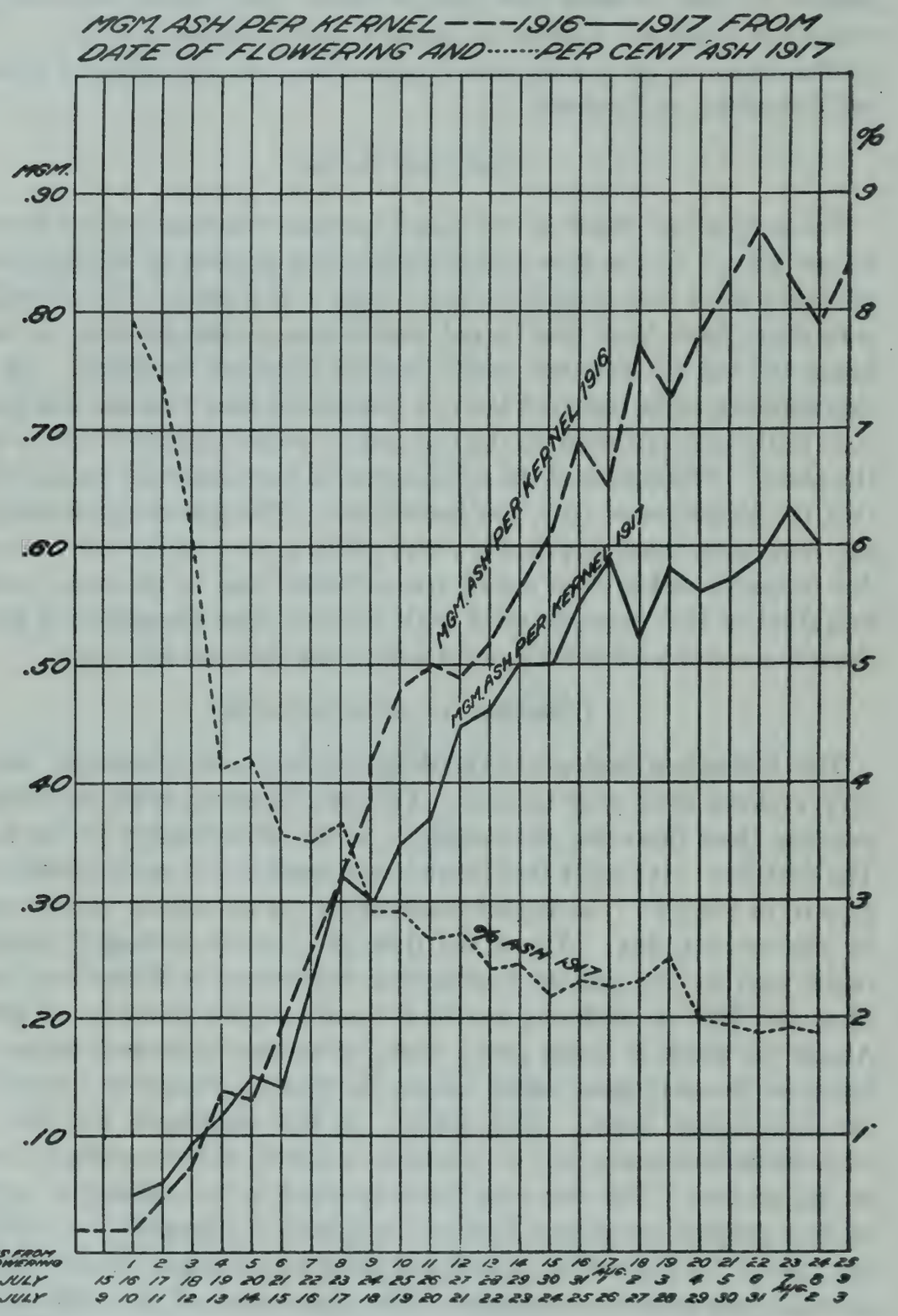

FIG. 16.—Graph showing ash per kernel from date of flowering in 1916 (broken line) and in 1917 (solid line) and the percentage of ash in 1917 (dotted line).

which are more or less deciduous, drop off in large numbers. The tissues of that part of the ovary above the embryo sac have been resorbed until it is possible at this stage to measure the kernel without including this

structure. The fifteenth or sixteenth day marks what probably is the most important change in the course of development. Among the internal changes, this date coincides with the maximum water content of the kernel and the end of the period of most rapid increase in dry matter and ash. Schjerning found a drop in the soluble nitrogen present in the kernel at about this time.

From the fifteenth or sixteenth day until maturity the changes are gradual and all in the same direction, differing only in degree. The only point now apparent, which might mark a change of nutrition, is to be found in those varieties which develop anthocyanin colors in the

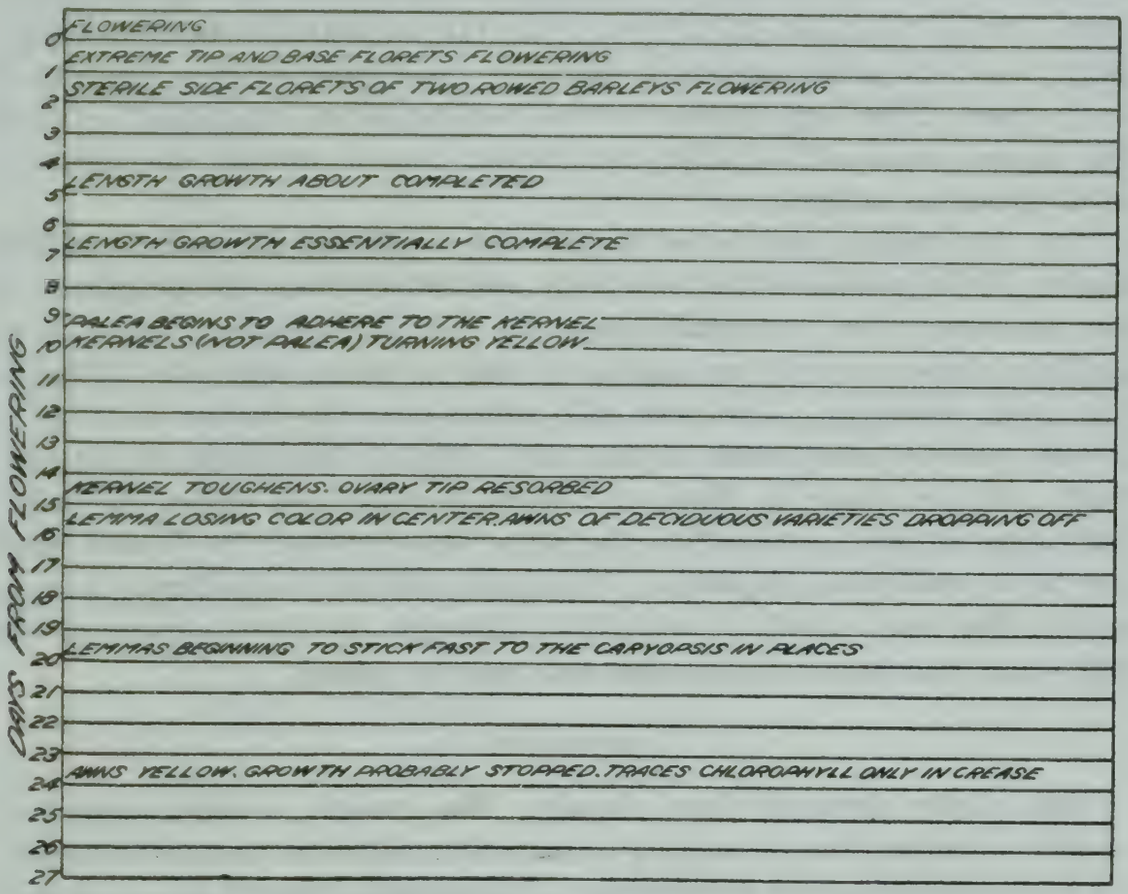

FIG. 17.—Periods of development of the barley kernel as indicated by records during three years at Aberdeen, Idaho.

external layers a few days before maturity. This is probably a very minor phase of metabolism, and at present it is not known to be associated with any vital phase of growth or maturation. The various external indices of internal changes are shown in figure 17.

MORPHOLOGICAL CHANGES

Microscopical examination of the kernel was made to determine the progress of the internal modifications that must accompany development. The starch infiltration is shown in various stages in Plates 85 to 91. Starch was found on the fourth day. This had increased perceptibly on the sixth day. The starch grains up to this time seemed

to be of a very much lower density than normal barley starch. They did not stain readily and were indefinite in outline. Rapid infiltration of starch began about the time that rapid growth of length ceased. By the ninth day after flowering the starch grains were of very uniform appearance. From this time the development was more irregular, not all the grains continuing to increase in size. By the fourteenth day small grains were apparent among the larger ones, as though new starch grains were forming. These small grains are found in the cells from this time until maturity. The fifteenth and sixteenth days represent a period when the awns are likely to drop off. The dropping of the awns, apparently, coincides with the completion of a stage of starch infiltration. From this time on, although the rate of starch deposit holds up fairly well, the accumulation is made by the continued development of only a part of the large grains and the packing of the interstices between the larger grains with smaller ones, rather than a uniform development of all grains as at first.

The first starch was found in the older cells in the middle of the flanks. It is probable that new cells are added about the peripheria of the endosperm and especially near the furrow for some time. It is unlikely that new cells are added to the peripheria after the fifteenth day from flowering. The new cells added near the furrow develop in a way entirely comparable to the first cells of the starch endosperm. Such cells are shown in Plate 91. After the first two weeks the transportation of food material to the sides remote from the furrow may not be so readily accomplished. Here the cells last formed may remain nearly free from starch at maturity, although the development of the cell walls demonstrates that the cells are not young.

SUMMARY

This paper presents data showing the growth of the Hannchen variety of barley from flowering to maturity, taken at 12-hour intervals. In the early stages of development, measurable growth occurs during 12-hour intervals, and during 24-hour intervals until near maturity. The period from flowering to maturity in three successive years at Aberdeen has been 26 days.

Measurements were taken of the length, lateral diameter, and dorsoventral diameter of the kernel. The growth immediately after flowering is so rapid that the increase in length is readily measurable at 12-hour intervals. The length growth is completed by the seventh day, and as soon as the rate of growth in length decreases the lateral diameter shows its most rapid increase. The dorsoventral diameter continues to increase almost until maturity. The increase in dry matter in the kernel is very uniform throughout the period of growth. The percentage of water decreases uniformly from flowering to maturity. During

growth the carbohydrates increase most rapidly and the ash least rapidly.

There are several well-marked steps in development. About the fifth or sixth day after flowering the growth in length is checked and a rapid gain in dry matter begins. About the ninth or tenth day a sticky substance is secreted, which causes the glumes to adhere to the kernel. About the fifteenth or sixteenth day the kernel toughens, the lemma begins to lose color in the dorsal surface, some of the awns drop off, and the kernel has reached its maximum water content.

Maturation occurs gradually. The cells about the furrow continue active longer than elsewhere. The actual date when growth ceases, even where the external conditions are unusually uniform, as they are at Aberdeen, must depend on the temperature and humidity at the time of ripening.

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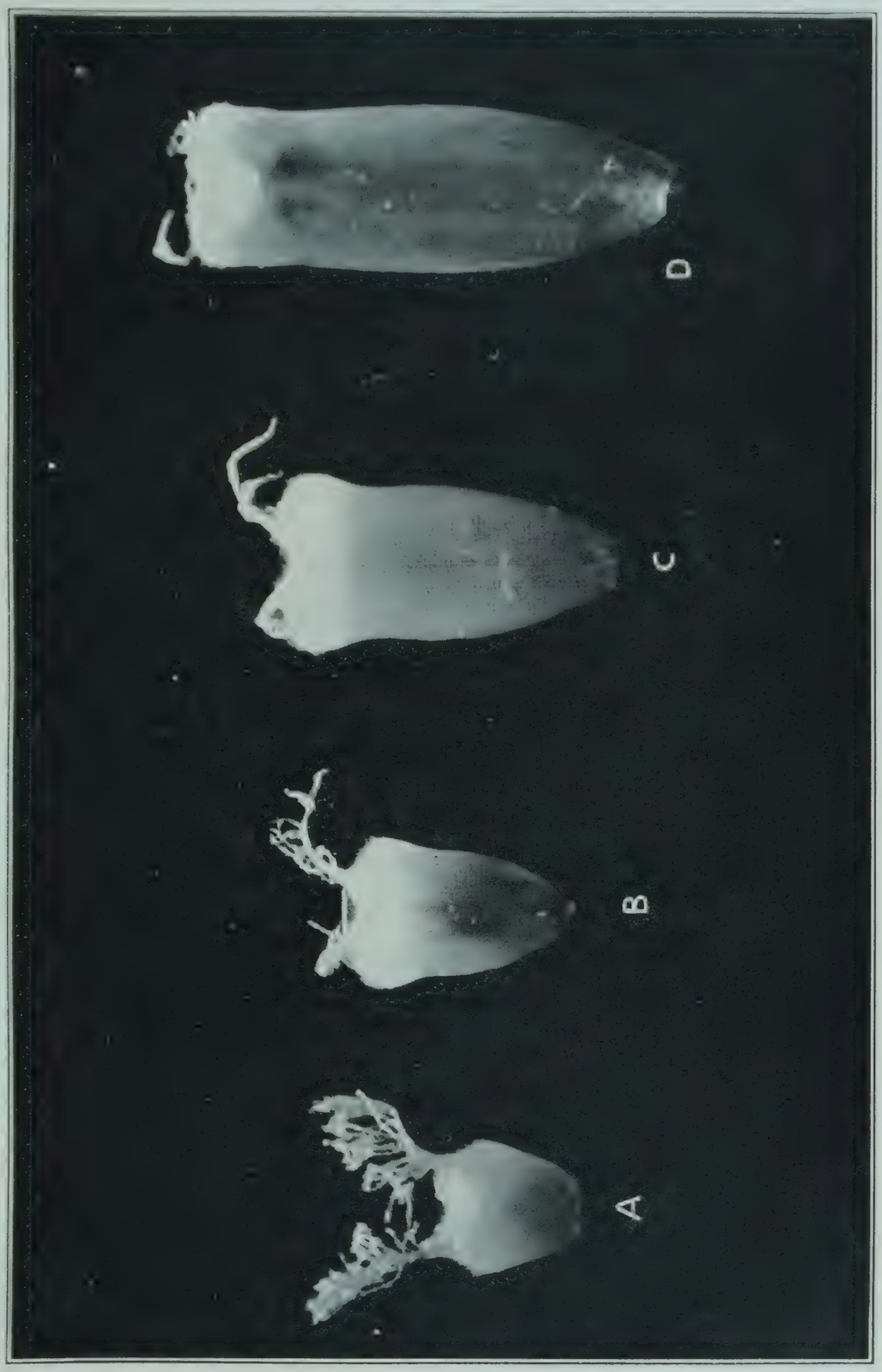
1906. ON THE PROTEIN SUBSTANCES OF BARLEY, IN THE GRAIN ITSELF AND DURING THE BREWING PROCESSES. *In* Compt. Rend. Trav. Lab. Carlsberg, v. 6, livr. 4, p. 229–307, 2 tab.

(7) ———
1914. ON THE PROTEID SUBSTANCES OF BARLEY, IN THE GRAIN ITSELF AND DURING THE BREWING PROCESSES. *In* Compt. Rend. Trav. Lab. Carlsberg, v. 11, livr. 2, p. 45–145. Literature cited, p. 146–147.

PLATE 83

A.—Fertilized ovary.
B.—Kernel 1 day old.
C.—Kernel 2 days old.
D.—Kernel 3 days old.


A
B
C
D

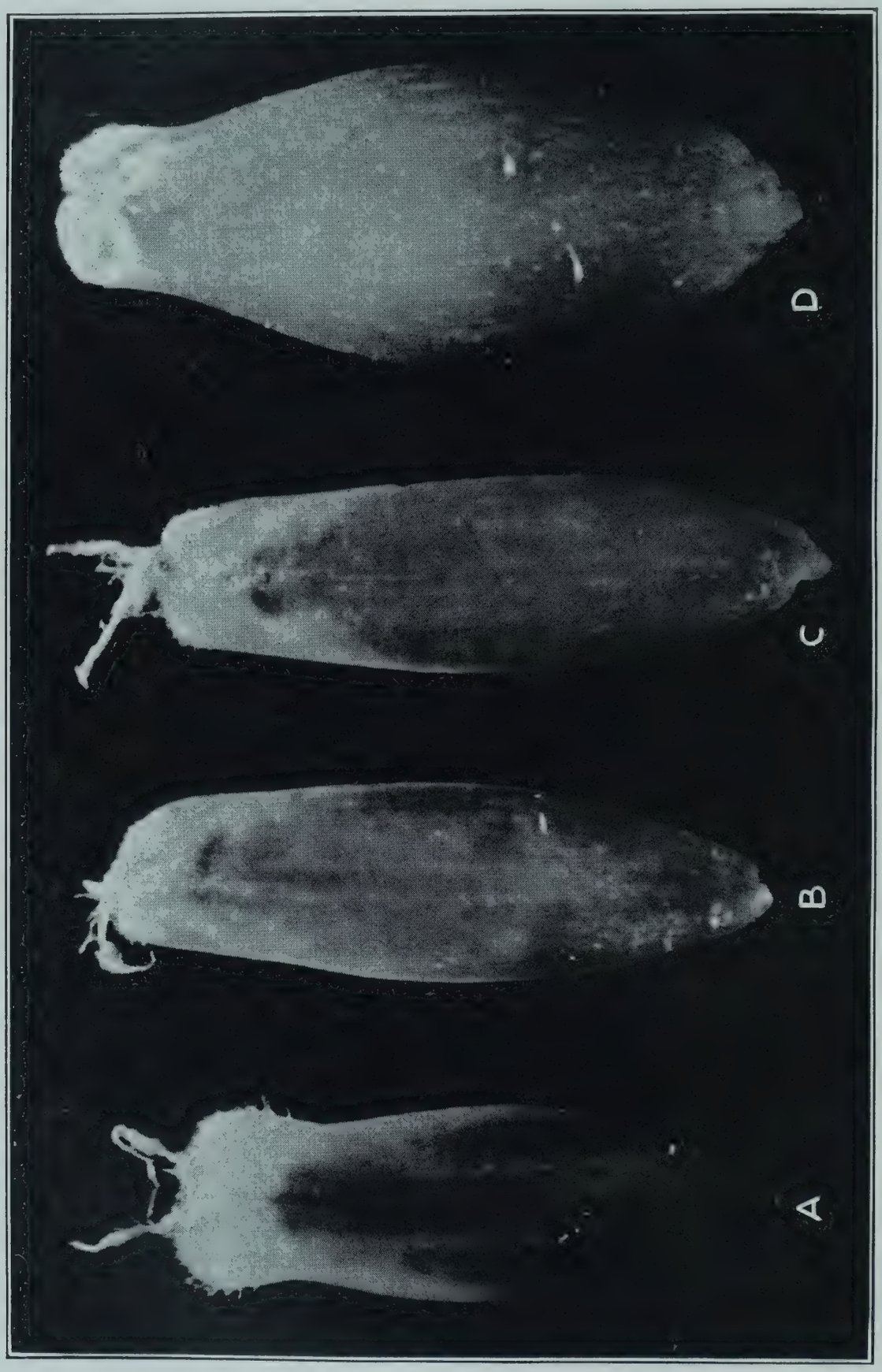
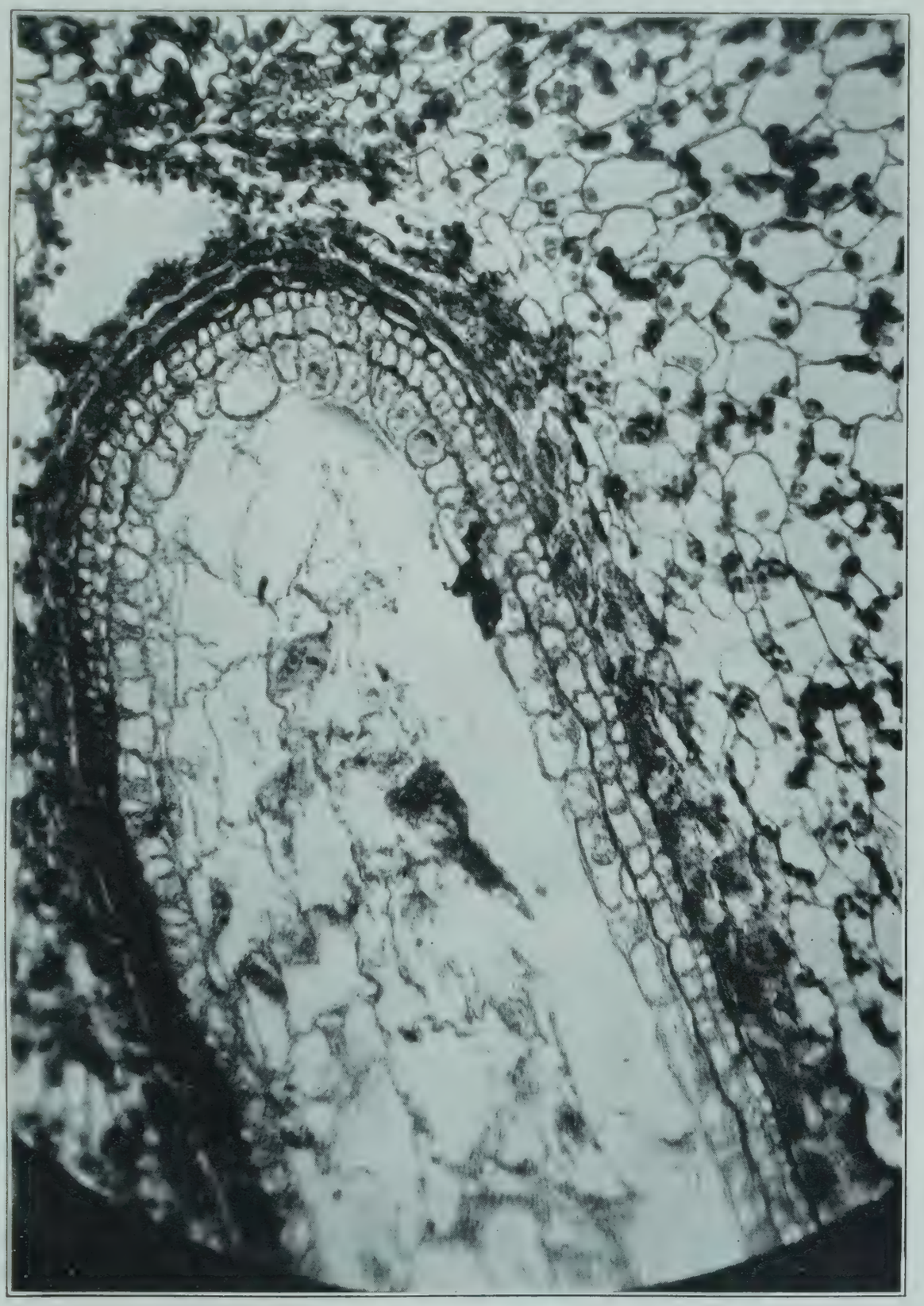

A
B
C
D

PLATE 84

A.—Kernel 4 days old.
B.—Kernel 5 days old.
C.—Kernel 6 days old.
D.—Kernel at later stage of development.

PLATE 85

Kernel 5 days after fertilization. Starch grains are apparent.



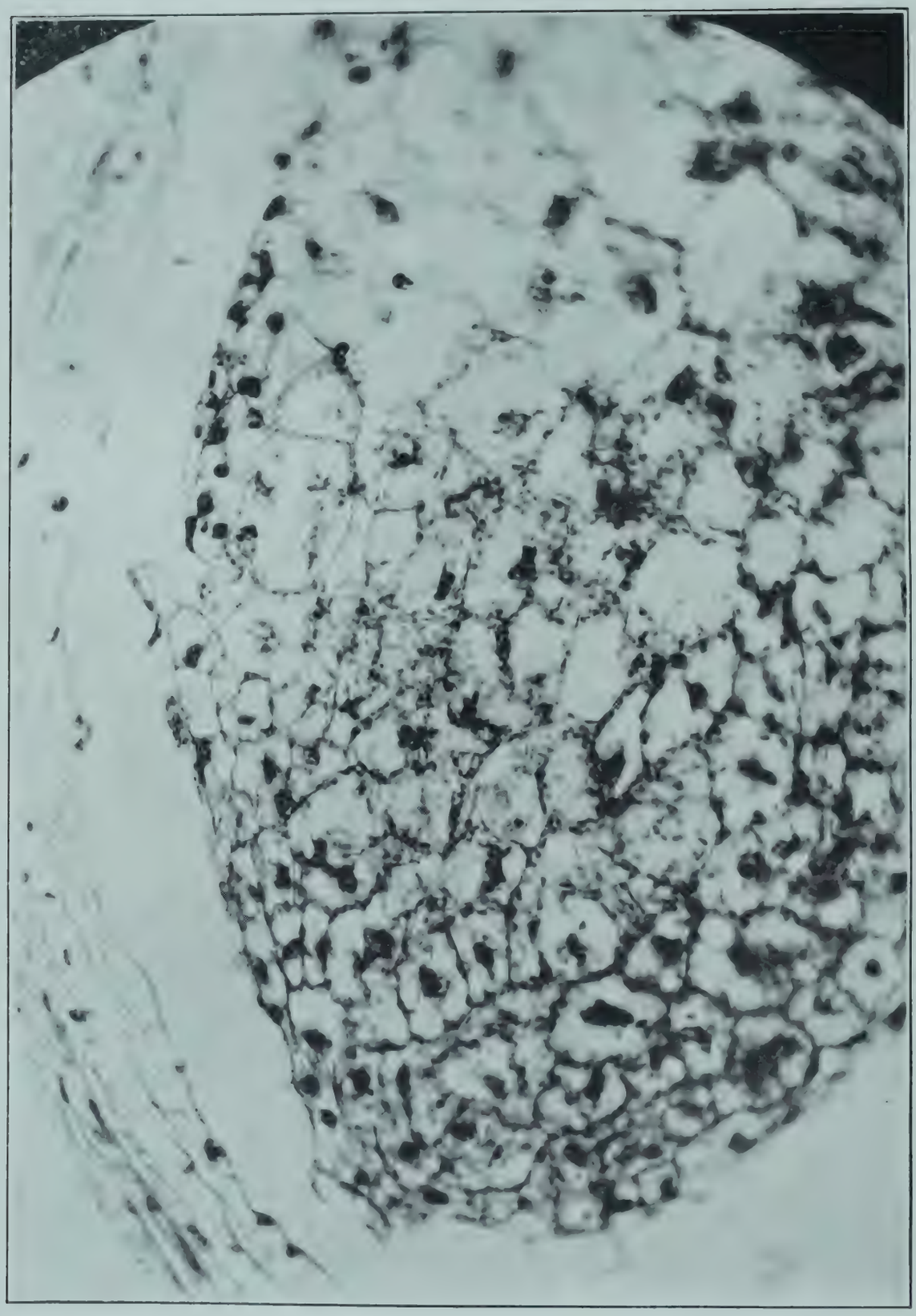


PLATE 86

Kernel 6 days after fertilization. Starch grains have increased greatly in numbers.

PLATE 87

Kernel 9 days after fertilization. The cells are well filled with starch grains of uniform size.

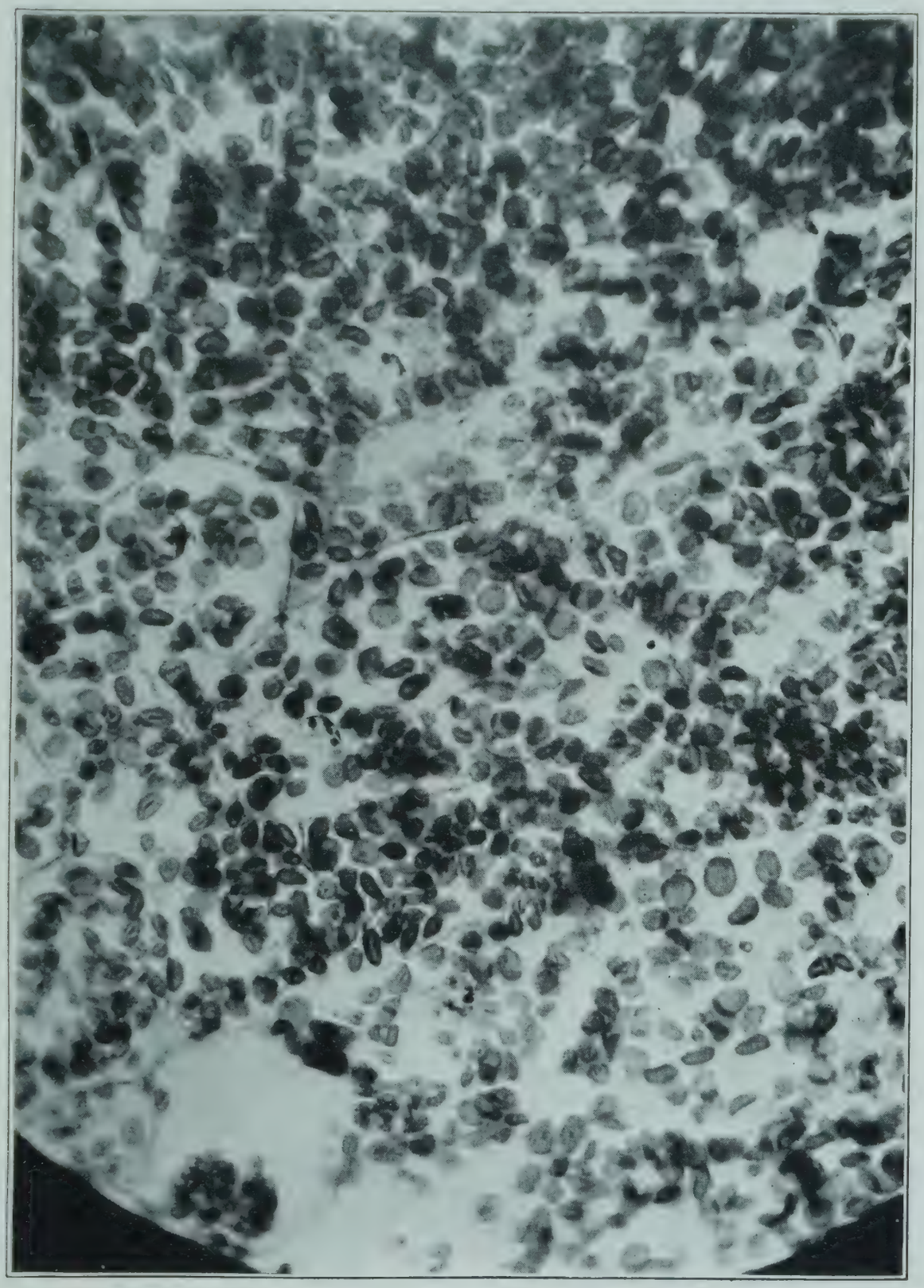
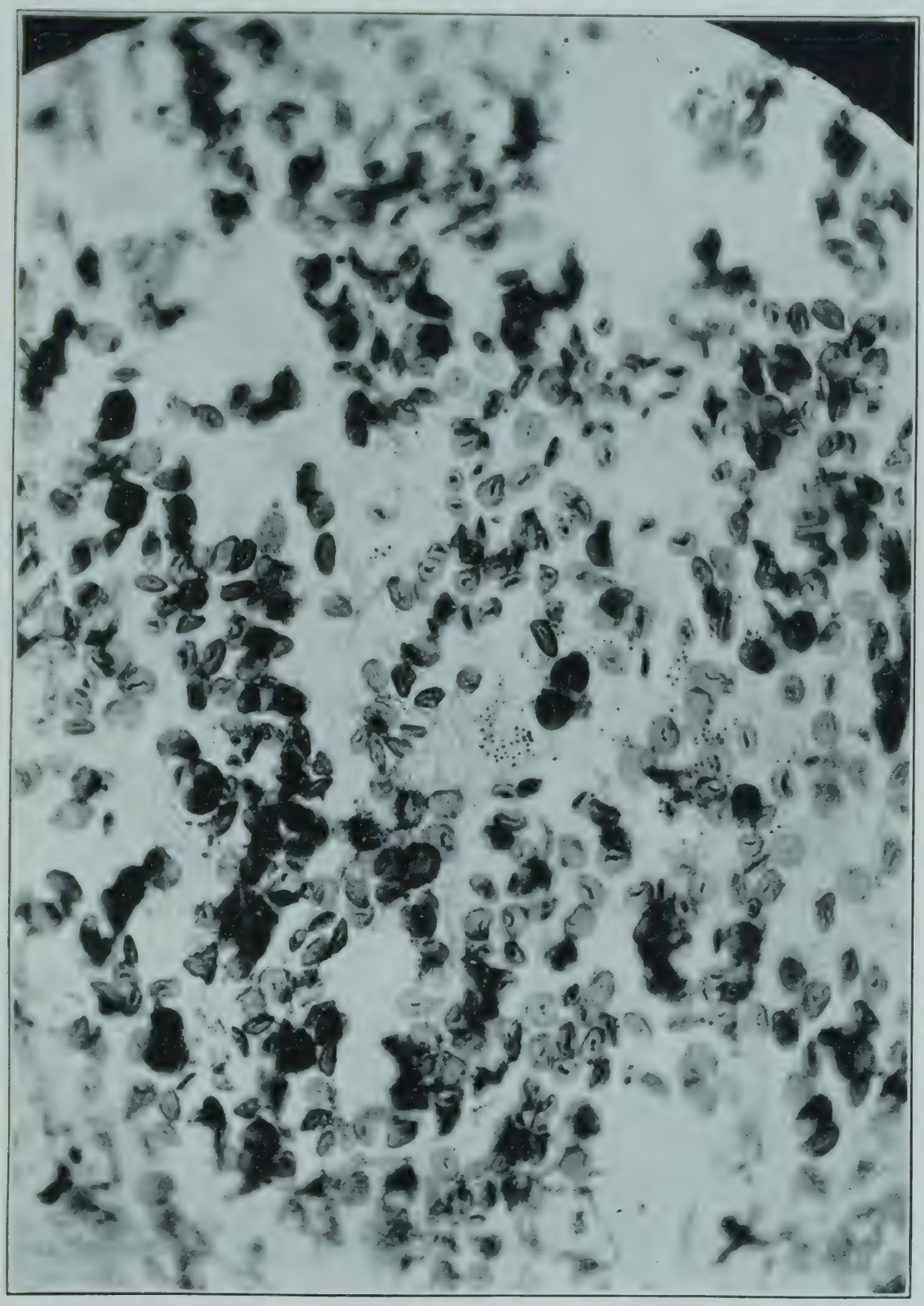


PLATE 88

Kernel 14 days after flowering. Both large and small starch grains are present.

PLATE 89

Kernel 20 days after fertilization, at which time growth was nearly completed.



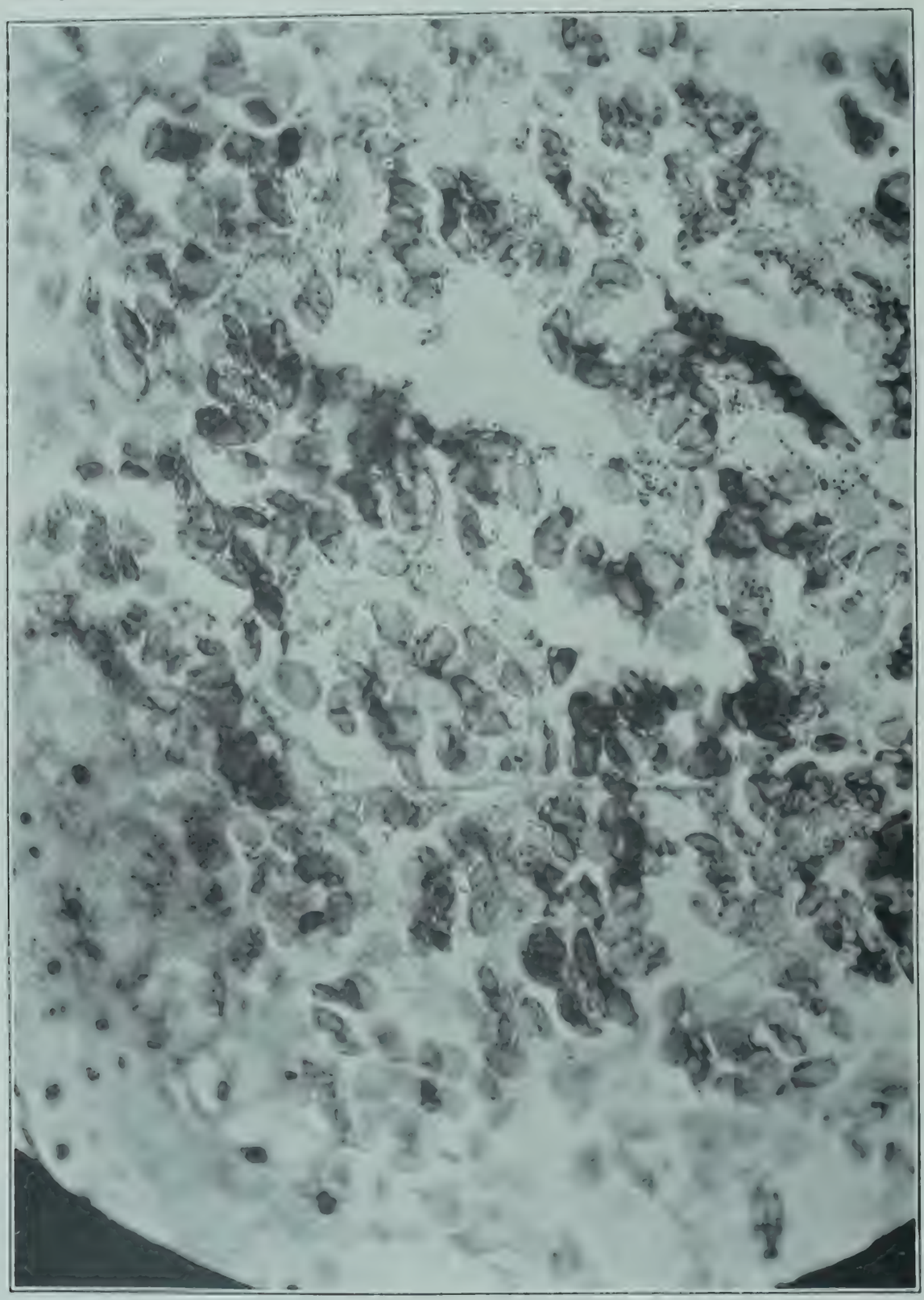
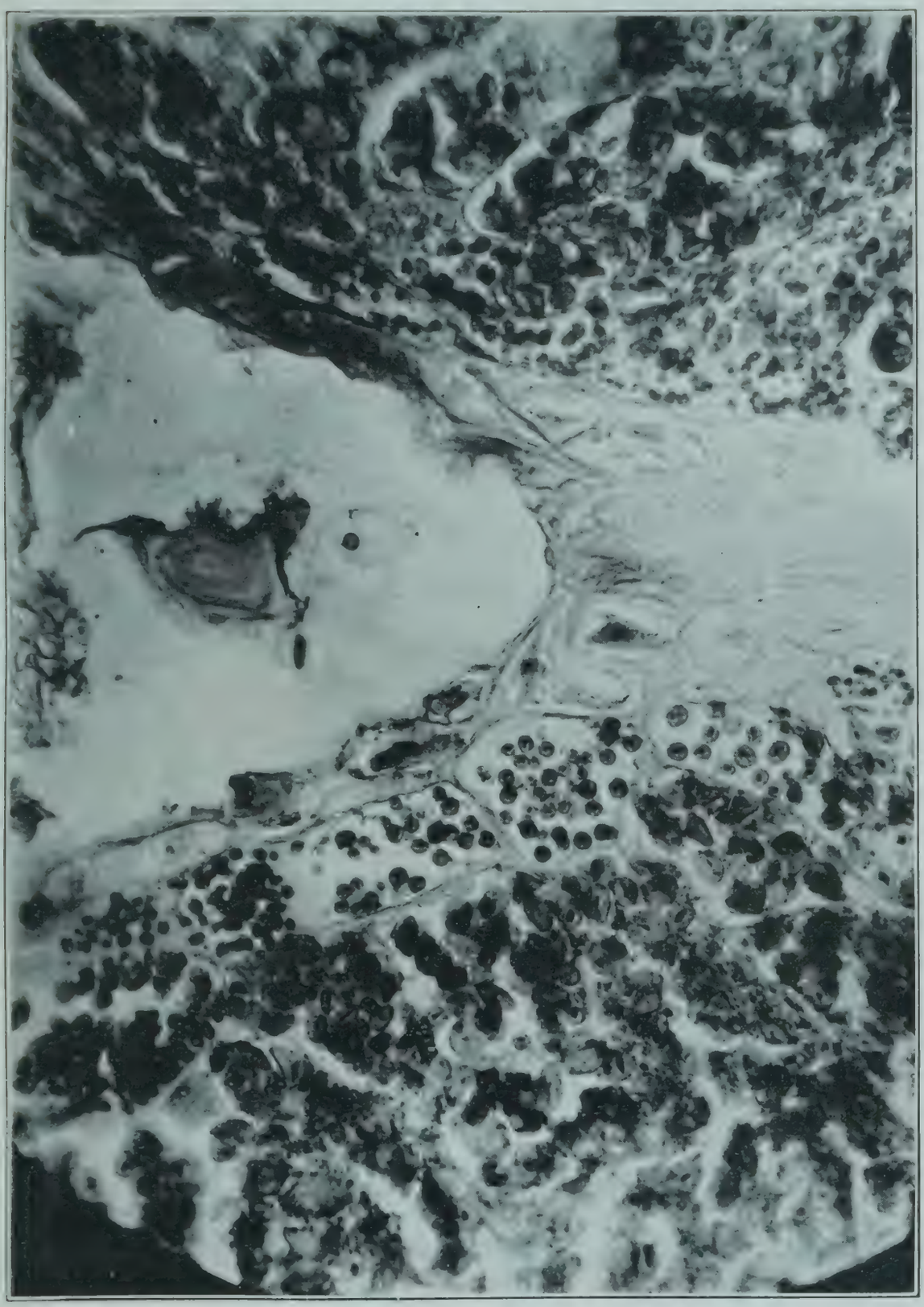


PLATE 90

Kernel 25 days after fertilization, growth completed.

PLATE 91

Section of a nearly mature kernel, showing cells next the furrow. These cells were formed more recently than those of the main starch endosperm.



DEVELOPMENT OF BARLEY KERNELS IN NORMAL AND CLIPPED SPIKES AND THE LIMITATIONS OF AWNLESS AND HOODED VARIETIES[1]

By HARRY V. HARLAN, *Agronomist in Charge of Barley Investigations*, and STEPHEN ANTHONY, *formerly Technologist in Barley Investigations, Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture*

INTRODUCTION

The studies reported in this paper were made in an effort to obtain some light on one of the farm problems in barley production. Among the farmers of the United States there is a strong prejudice against the growing of barley because the long, rough awns make the crop disagreeable to handle. The beards in barley straw and hay often cause sore mouths in stock. Barley straw and barley hay are also undesirable for feeding to sheep because the awns work into the wool. It is only the high acre yield in pounds of feed that has maintained the acreage of this crop, but this acreage is far below that which would be devoted to barlev if the awns were lacking.

Certain types of barley are free from the harsh awns. One of these, the Nepal, produces hoods in the place of awns. This variety, under various names, has been more frequently introduced and more widely tested than any other. Many hybrids have been made and distributed. That they have failed to measure up to the expectations is evident in the annual inquiry of seedsmen as to where they can secure seed of "bald" barley.

The only apparent explanation of the failure of the Nepal barley is the lack of awns. The field records of the Office of Cereal Investigations, extending over many years, indicate that the Nepal compares favorably with other varieties only in the high altitudes and in dry years in the northern part of the Great Plains area. As a rule, varieties of this type have yielded less than the awned sorts and have shattered badly. It is evident that the awn is an organ that is functional under most conditions, and especially in those sections where humid weather prevails at ripening time.

Zoebl and Mikosch [2] in 1892 showed that the awn of barley was an organ of transpiration. Schmid [3] in 1898 and Perlitus [4] in 1903 elaborated the experiments of Zoebl and Mikosch. All agreed that the awn was an organ of transpiration and all showed the effect of its removal on both the rate of transpiration and the kernel.

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[1] These studies were made on the Aberdeen Substation, Aberdeen, Idaho, in connection with cereal experiments conducted cooperatively by the Idaho Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture.

[2] ZOEBL, A., and MIKOSCH, C. DIE FUNCTION DER GRANNEN DER GERSTENÄHRE. *In* Sitzber. K. Akad, Wiss. [Vienna], Math. Naturw. Cl., Bd. 101, Abt. 1, Heft 9/10, p. 1033–1060. 1892.

[3] SCHMID, B. BAU UND FUNKTIONEN DER GRANNEN UNSERER GETREIDEARTEN. *In* Bot. Centbl., Bd. 76, p. 39, 75, 119, 218, 305–307. 1898.

[4] PERLITUS, Ludwig. EINFLUSS DER BEGRANNUNG AUF DIE WASSERVERDUNSTUNG DER AEHREN UND DIE KORNQUALITÄT. 77 p., 3 pl. Breslau, 1903.

EXPERIMENTAL METHODS AND MATERIAL

The first experiment by the present writer was a very elementary one made in Minnesota in 1911. It included yield only. Plants from which the awns were clipped produced only 75 per cent of the yield of normal plants.

In this and the later experiments, sufficient spikes of the same age were tagged on the same day. The method used was that described in an earlier paper.[1] The awns on half the spikes were removed even with the top of the upper most sheath as fast as they appeared. In clipping the awns it was necessary to examine the heads each day for three or four days.

It is apparent that mechanical injuries might result from this operation which would affect the later growth of the spike. For this reason it was thought desirable to trace the growth throughout the period from flowering to maturity. The number tagged was sufficient for a sample of two or three spikes per day from both the clipped and the normal plants for a period of 30 days. In a preliminary experiment at Arlington Farm, Va., in May, 1915, it was found that the taking of daily samples was practicable. In July, 1915, a complete experiment was conducted with the Manchuria barley at University Farm, St. Paul, Minn., and in the summer of 1916 a similar experiment was conducted at Aberdeen, Idaho, with Hannchen barley. The weights, lengths, and diameters of the kernels of the samples were obtained daily. The kernels were later analyzed to determine the nitrogen and ash. The results from the two varieties will be presented separately.

EFFECT OF REMOVING THE AWNS FROM MANCHURIA BARLEY IN MINNESOTA

The Manchuria is a 6-rowed variety of barley. It is awned, a vigorous grower, and adapted to fairly humid climatic conditions. It cannot be grown in the arid districts with success. The first sample at Minnesota was taken on July 1, 1915; and samples were taken daily until August 7, with the exception of five days. This was the only study conducted in Minnesota. Table I shows the data obtained at St. Paul, Minn., in a humid district, with the variety of barley best adapted to that district. The samples taken in Minnesota differ from those taken at Aberdeen in that they consist of a single spike each day. The weights and measurements of the individual lateral and central kernels on one side of the spike were taken under each of the headings "weight," "length," etc., in Table I. The first column contains the weight and measurement of a lateral kernel, the second contains those of the central kernel, and the third contains those of the remaining lateral kernels at the same rachis node. The kernels were studied in order from the base of the spike upward. In the first line under each date are the data from the first fertile florets at the base of the spike. In the second line are the observations on the florets at the node above. The last line contains the data on the last fertile florets at the tip of the spike.

[1] HARLAN, HARRY V. DAILY DEVELOPMENT OF KERNELS OF HANNCHEN BARLEY FROM FLOWERING TO MATURITY AT ABERDEEN, IDAHO. *In* Jour. Agr. Research, v. 19, no. 9, p. 393–430. 1920.

TABLE I.—*Development of kernels of Manchuria barley from flowering to maturity in normal and clipped spikes at St. Paul, Minn., 1915*

JULY 1

Normal spikes.												Clipped spikes.											
Weight.			Length.			Lateral diameter.			Dorsoventral diameter.			Weight.			Length.			Lateral diameter.			Dorsoventral diameter.		
Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.
Gm.	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0007	0.0011	0.0007	1.9	1.9	1.8	0.6	0.6	0.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0009	.0011	.0009	2.0	2.2	1.9	.6	.7	.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0009	.0012	.0009	1.7	1.9	1.8	.7	.7	.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0010	.0012	.0010	2.0	1.9	1.9	.7	.7	.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0011	.0012	.0010	1.9	1.9	2.1	.7	.8	.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0012	.0014	.0009	1.7	2.2	1.9	.8	.8	.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0008	.0011	.0007	2.0	2.0	1.8	.7	.7	.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0007	.0011	.0008	2.2	2.6	1.5	.7	.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

JULY 2

0.0009	0.0014	0.0009	2.1	2.3	1.7	0.6	0.6	0.6	.....	.....	.....	0.0010	0.0021	0.0010	1.9	2.4	2.3	0.7	0.6	0.6	.....	.....	.....
.0012	.0017	.0012	1.9	2.3	2.1	.6	.9	.7	.....	.....	.....	.0011	.0023	.0012	2.1	2.6	2.2	.7	.8	.6	.....	.....	.....
.0012	.0019	.0015	2.2	2.6	2.2	.7	.8	.8	.....	.....	.....	.0018	.0025	.0017	2.5	2.7	2.5	.9	1.0	.8	.....	.....	.....
.0013	.0021	.0013	2.2	2.2	2.0	.8	1.6	.6	.....	.....	.....	.0019	.0026	.0018	2.4	2.9	2.6	.7	.9	.7	.....	.....	.....
.0012	.0022	.0012	1.7	2.5	1.7	.8	.7	.7	.....	.....	.....	.0020	.0027	.0019	2.4	2.7	2.6	.9	1.0	.8	.....	.....	.....
.0012	.0019	.0015	2.2	2.5	2.2	.6	.8	.7	.....	.....	.....	.0020	.0028	.0020	2.5	2.7	2.4	.9	.9	.8	.....	.....	.....
.0013	.0018	.0014	2.3	2.5	2.4	.8	.8	.7	.....	.....	.....	.0017	.0028	.0017	2.5	2.8	2.0	.8	1.0	.8	.....	.....	.....
.0014	.0018	.0013	2.3	2.4	2.3	.7	.8	.7	.....	.....	.....	.0015	.0024	.0016	2.2	2.2	2.3	.8	.9	.8	.....	.....	.....
.0012	.0017	.0012	2.4	2.3	1.9	.7	.9	.8	.....	.....	.....	.0013	.0018	.0014	1.8	2.2	2.1	.7	.7	.5	.....	.....	.....
.0011	.0013	.0012	1.7	2.0	2.1	.7	.7	.8	.....	.....	.....	.0008	.0011	.0008	1.7	1.9	1.5	.8	.7	.6	.....	.....	.....
.0003	.0006	.0003	1.1	1.4	1.2	.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

183718°—20——4

TABLE I.—*Development of kernels of Manchuria barley from flowering to maturity in normal and clipped spikes at St. Paul, Minn., 1915*—Con.

JULY 3

Normal spikes.												Clipped spikes.											
Weight.			Length.			Lateral diameter.			Dorsoventral diameter.			Weight.			Length.			Lateral diameter.			Dorsoventral diameter.		
Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.
Gm.	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0012	0.0017	0.0006	1.9	2.2	1.2	0.5	0.8	0.0	.....	.....	.....	0.0010	0.0015	S	1.9	2.2	S	0.7	0.7	S	.....	.....	.....
.0013	.0020	.0013	2.0	2.3	2.0	.7	.7	.7	.....	.....	.....	.0012	.0022	0.0013	2.0	2.4	2.0	.6	.7	.7	.....	.....	.....
.0013	.0023	.0014	2.1	2.5	2.1	.8	.9	.7	.....	.....	.....	.0014	.0023	.0016	2.1	2.5	2.2	.8	.8	.7	.....	.....	.....
.0014	.0023	.0014	2.1	2.5	2.2	.8	1.0	.7	.....	.....	.....	.0016	.0025	.0016	2.2	2.5	2.2	.6	.8	.7	.....	.....	.....
.0014	.0018	.0014	2.0	2.2	2.1	.8	.7	.7	.....	.....	.....	.0017	.0028	.0017	2.4	2.8	2.5	.7	1.3	.7	.....	.....	.....
.0014	.0018	.0013	2.1	2.1	2.3	.6	.8	.6	.....	.....	.....	.0015	.0020	.0016	2.1	2.5	2.3	.8	.7	.9	.....	.....	.....
.0015	.0018	.0014	2.1	2.0	1.9	.7	.9	.7	.....	.....	.....	.0016	.0019	.0015	2.1	2.4	2.0	.6	.6	.9	.....	.....	.....
.0014	.0018	.0014	1.9	1.8	1.7	.9	.7	.7	.....	.....	.....	.0015	.0018	.0015	2.0	1.9	1.8	.7	.8	.7	.....	.....	.....
.0012	.0016	.0009	2.3	2.0	2.0	.8	.8	.8	.....	.....	.....	.0012	.0016	.0012	1.8	2.1	1.9	.7	.7	.6	.....	.....	.....
.0004	.0007	[a]S	1.4	1.4	S	.4	.8	S	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

JULY 5

0.0014	0.0025	0.0014	2.1	2.7	2.2	0.7	0.7	0.7	0.7	0.7	0.5	0.0014	0.0031	0.0015	2.2	2.9	2.2	0.7	1.5	0.9	0.6	0.8	0.7
.0018	.0029	.0018	2.3	2.8	2.2	.9	1.2	.8	.6	.8	.6	.0021	.0038	.0019	2.5	2.6	2.4	1.1	1.3	1.0	.7	.9	.7
.0018	.0030	.0018	2.2	3.0	2.3	.6	1.0	.6	.6	.9	.5	.0022	.0037	.0022	2.9	3.0	2.4	1.3	1.3	1.1	.8	.7	.8
.0018	.0030	.0026	2.3	2.4	2.4	.7	1.0	1.1	.6	1.0	.8	.0028	.0040	.0029	2.4	2.8	3.0	1.3	1.3	1.3	.9	.8	.8
.0018	.0031	.0019	2.2	2.2	2.2	.9	1.4	.9	.7	.8	.6	.0025	.0041	.0025	2.6	3.3	2.5	1.3	1.3	1.2	.8	.8	.8
.0018	.0029	.0019	2.3	2.1	2.3	.7	1.0	.9	.5	.9	.5	.0030	.0039	.0025	3.2	3.2	2.1	1.3	1.4	1.3	1.0	1.0	.7
.0016	.0029	.0016	2.1	2.3	2.2	.7	1.3	.8	.5	.9	.6	.0027	.0037	.0025	2.5	2.6	2.5	1.3	1.4	1.1	.8	1.0	.....
.0016	.0023	.0016	2.1	2.5	2.1	.9	.9	1.0	.7	.7	.7	.0020	.0027	.0020	1.9	2.3	2.1	1.0	1.1	.9	.....	.....	.....
.0013	.0019	.0014	1.9	2.3	1.9	.8	.9	.7	.7	.7	.6	.0016	.0020	.0014	2.2	2.0	2.1	.6	.8	.7	.....	.....	.....
S	S	S	S	S	S	S	S	S	S	S	S	.0006	.0009	.0006	1.3	1.4	1.3	.....	.6	.....	.....	.....	.....

[a] The letter S indicates a sterile spikelet.

JULY 7

0.0050	0.0098	0.0045	4.1	5.6	3.6	1.4	1.6	1.3	1.0	1.2	0.9	0.0048	0.0078	0.0052	3.7	4.5	3.8	1.4	1.8	1.3	1.1	1.1	1.0
.0062	.0108	.0055	4.4	5.2	4.1	1.6	1.8	1.5	1.0	1.3	.8	.0057	.0102	.0064	4.1	5.7	4.3	1.5	1.7	1.5	1.0	1.1	1.0
.0073	.0123	.0070	4.7	6.4	4.5	1.6	2.0	1.5	1.0	1.2	1.1	.0075	.0085	.0069	4.7	4.6	4.5	1.5	1.6	1.5	1.0	1.1	1.0
.0079	.0126	.0069	4.6	6.1	4.3	1.6	1.9	1.6	1.1	1.2	1.2	.0075	.0088	.0074	4.4	4.7	4.6	1.6	1.6	1.6	1.2	1.2	1.0
.0087	.0125	.0070	5.0	6.1	4.6	1.7	1.9	1.6	1.2	1.2	1.1	.0069	.0092	.0072	4.1	4.8	4.3	1.4	1.7	1.6	1.0	1.1	1.2
.0081	.0116	.0072	4.9	5.7	4.3	1.7	1.8	1.5	1.0	1.1	1.1	.0070	.0082	.0072	4.1	4.3	4.3	1.5	1.5	1.5	1.1	1.2	1.1
.0067	.0712	.0062	4.0	5.3	3.7	1.5	1.8	1.4	1.1	1.1	1.0	.0060	.0079	.0046	4.1	4.3	3.5	1.4	1.5	1.4	1.0	1.1	.9
.0037	.0074	.0037	2.8	4.0	2.7	1.2	1.6	1.3	.9	1.1	1.0	.0030	.0073	.0030	2.5	4.8	2.5	1.2	1.4	1.2	.9	1.1	.9
.0034	.0038	.0030	3.1	2.8	2.4	1.3	1.3	1.2	.8	.9	.9	.0023	.0032	.0021	2.7	2.5	2.3	.8	1.2	.7	.9	1.0	.6

JULY 8

0.0051	0.0095	0.0047	3.9	5.3	3.8	1.4	1.7	1.4	1.0	1.1	0.9	0.0023	0.0048	0.0020	2.2	3.7	2.2	1.0	1.3	1.0	0.7	0.8	0.7
.0080	.0100	.0063	4.9	5.6	4.3	1.6	1.8	1.4	1.0	1.1	1.1	.0033	.0072	.0036	3.0	4.7	3.4	1.2	1.7	1.4	.8	1.0	.8
.0085	.0100	.0057	4.9	4.8	4.1	1.6	1.7	1.4	1.1	1.1	1.1	.0049	.0081	.0051	3.9	4.8	4.0	1.4	1.7	1.4	1.0	1.0	.8
.0084	.0102	.0066	4.7	5.1	4.2	1.5	1.7	1.6	1.0	1.2	1.1	.0061	.0083	.0044	4.5	4.8	3.7	1.6	1.8	1.3	1.1	1.1	1.0
.0088	.0110	.0082	5.0	5.4	5.0	1.5	1.7	1.7	1.2	1.2	1.2	.0050	.0027	.0063	3.5	2.3	4.3	1.5	.7	1.5	.8	.....	1.0
.0062	.0106	.0080	4.0	5.2	4.5	1.4	1.6	1.7	1.1	1.2	1.1	.0054	.0063	.0051	4.0	4.1	3.6	1.5	1.4	1.5	1.0	1.1	1.0
.0059	.0066	.0059	4.1	4.1	3.8	1.4	1.5	1.5	1.0	1.2	1.0	.0052	.0062	.0053	3.8	3.8	3.7	1.5	1.5	1.5	1.1	1.1	1.1
.0056	.0065	.0055	3.8	4.0	3.8	1.5	1.5	1.5	1.0	1.1	1.0	.0046	.0064	.0049	3.7	4.1	3.8	1.4	1.5	1.5	1.1	1.0	1.0
.0041	.0061	.0026	3.4	4.1	2.6	1.3	1.5	1.2	.8	1.1	.7	.0038	.0065	.0026	3.0	4.0	2.7	1.3	1.4	1.1	1.0	1.0	.9
.....	.0019	.....	S	2.6	S	.....	2.0	.....	.....	.....	.7	.....	.0024	.0028	.0025	2.5	2.5	2.5	1.1	1.2	1.1	.8	1.0	.8
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.0014	.0021	.0014	2.1	2.4	2.2	.7	.9	.9	.7	.7	.6
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S	S	S	S	S	S	S	S	S	S	S	S

JULY 9

S	0.0074	S	S	4.7	S	S	1.8	S	S	0.9	S	0.0066	0.0100	0.0068	5.1	5.9	4.9	1.6	1.7	1.7	0.9	1.0	1.0
0.0068	.0091	0.0066	4.4	4.4	4.2	1.6	1.6	1.5	1.0	1.3	1.2	.0084	.0117	.0072	5.6	6.5	5.0	1.6	1.9	1.4	1.0	1.3	1.1
.0080	.0095	.0083	4.9	5.4	5.1	1.7	1.8	1.8	1.0	1.2	1.1	.0109	.0121	.0098	6.2	6.5	5.9	1.8	1.8	1.8	1.2	1.2	1.1
.0082	.0126	.0099	4.9	6.5	5.7	1.7	2.0	1.8	1.2	1.3	1.1	.0106	.0123	.0105	6.2	6.6	5.8	1.8	2.0	1.7	1.1	1.2	1.1
.0089	.0137	.0084	5.4	6.9	4.9	1.8	1.8	1.8	1.2	1.2	1.2	.0107	.0130	.0111	6.3	6.9	6.0	2.0	1.9	1.9	1.1	1.2	1.1
.0087	.0099	.0084	5.0	5.1	4.9	1.8	1.8	1.9	1.2	1.2	1.2	.0109	.0130	.0091	6.0	6.4	5.0	1.9	1.9	1.7	1.1	1.2	1.2
.0088	.0104	.0103	5.0	5.7	5.5	1.8	1.9	2.1	1.2	1.3	1.2	.0120	.0135	.0085	6.7	6.7	5.0	1.8	1.8	1.6	.....	1.3	1.2
.0086	.0125	.0101	4.7	6.3	5.6	1.7	1.9	1.9	1.2	1.3	1.2	.0082	.0146	.0088	4.7	7.2	5.0	1.5	2.0	1.7	1.1	1.2	1.1
.0072	.0102	.0047	4.2	5.0	3.3	1.5	1.7	1.4	1.1	1.2	.9	.0088	.0142	.0079	5.2	7.3	5.0	1.7	2.0	1.6	1.1	1.2	1.1
.0039	.0049	.0037	2.9	3.4	2.8	1.3	1.4	1.4	.9	.9	.9	.0049	.0087	.0049	3.6	5.0	3.8	1.4	1.7	1.3	1.0	1.2	.9
.0010	.0017	.0010	1.7	2.1	1.6	.8	.8	.9	.....	.....	.....	.0013	.0027	.0014	1.7	2.6	1.9	.8	1.0	.9	.5	.8	.5

TABLE I.—*Development of kernels of Manchuria barley from flowering to maturity in normal and clipped spikes at St. Paul, Minn., 1915*—Con.

JULY 10

Normal spikes.													Clipped spikes.											
Weight.			Length.			Lateral diameter.			Dorsoventral diameter.				Weight.			Length.			Lateral diameter.			Dorsoventral diameter.		
Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.		Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.
Gm.	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*		*Gm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0096	0.0129	0.0098	5.9	6.6	5.9	.....	1.8	1.8	1.2	1.3	1.0		0.0069	0.0157	0.0078	5.0	7.6	5.4	1.7	2.3	1.6	1.0	1.5	1.0
.0114	.0149	.0109	6.4	7.4	6.3	2.0	2.0	1.9	1.0	1.3	1.1		.0095	.0150	.0088	5.5	7.4	6.0	1.7	2.2	1.8	1.2	1.3	1.3
.0123	.0168	.0107	6.4	7.4	5.9	2.0	2.3	1.8	1.2	1.3	1.3		.0108	.0152	.0085	6.7	7.6	5.8	1.9	2.1	1.6	1.3	1.5	1.2
.0132	.0159	.0128	6.7	7.8	6.9	2.0	2.2	2.0	1.3	1.4	1.3		.0121	.0160	.0106	7.0	8.1	6.2	1.8	2.2	1.8	1.2	1.5	1.4
.0127	.0175	.0123	7.2	8.4	6.7	2.0	2.3	2.1	1.2	1.5	1.2		.0138	.0162	.0134	7.6	7.8	7.4	1.9	2.2	2.0	1.4	1.5	1.4
.0130	.0181	.0131	6.8	8.1	6.7	1.9	2.3	1.9	1.3	1.4	1.1		.0144	.0169	.0134	7.8	8.1	7.6	2.0	2.2	2.0	1.5	1.5	1.4
.0131	.0178	.0130	6.2	8.5	7.0	2.0	2.3	2.0	1.3	1.5	1.2		Lost.	.0167	.0119	.....	8.0	6.8	.....	3.2	1.9	.....	1.5	1.2
S	.0142	.0110	S	6.9	5.7	S	1.9	1.9	S	1.3	1.2		Dead.	.0164	.0099	.....	7.8	5.6	.....	2.1	1.8	.....	1.4	1.1
.0078	.0135	.0070	4.3	6.6	4.4	1.6	1.9	1.6	1.1	1.3	.9		.0080	.0138	.0070	5.5	7.0	5.0	1.7	2.1	1.5	1.0	1.3	1.0
.0029	.0055	.0021	3.2	4.1	2.3	1.1	1.8	1.0	.8	.8	.6		S	S	S	S	S	S	S	S	S	S	S	S

JULY 11

0.0139	0.0208	0.0153	7.9	8.7	7.9	2.1	2.4	2.3	1.4	1.6	1.4		Dying.	0.0139	0.0088	.....	7.7	6.2	.....	2.1	1.7	.....	1.5	1.2
.0186	.0213	.0172	8.4	8.6	8.1	2.3	2.4	2.2	1.6	1.6	1.6		0.0121	.0172	.0108	7.7	7.8	6.8	2.0	2.0	1.7	1.4	1.5	1.3
.0184	.0225	.0175	8.6	9.5	8.2	2.4	2.5	2.3	1.7	1.6	1.7		.0163	.0187	.0132	7.8	7.6	7.1	2.2	2.5	2.1	1.5	1.6	1.5
.0201	.0241	.0194	9.0	9.3	8.9	2.4	2.4	2.3	1.6	1.8	1.7		.0166	.0216	.0170	7.7	8.7	8.2	2.1	2.4	2.2	1.5	1.7	1.5
.0196	.0250	.0205	8.7	9.8	8.8	2.2	2.5	2.4	1.5	1.8	1.7		.0183	.0217	.0126	8.4	8.7	7.4	2.2	2.4	2.1	1.5	1.6	1.4
.0210	.0230	.0150	8.7	9.5	7.8	2.3	2.3	2.1	1.7	1.7	1.4		.0190	.0222	.0202	8.2	8.9	9.1	2.3	2.3	2.3	1.7	1.7	1.6
.0157	.0229	.0150	7.8	9.2	7.3	2.2	2.3	2.1	1.5	1.7	1.5		.0187	.0228	.0198	8.2	9.0	8.5	2.3	2.3	2.3	1.7	1.8	1.6
.0153	.0225	.0147	7.5	9.3	7.5	2.2	2.3	2.1	1.4	1.6	1.3		.0190	.0221	.0195	8.6	9.2	8.8	2.2	2.3	2.3	1.5	1.6	1.5
.0130	.0158	.0108	7.1	7.8	5.9	2.2	2.0	1.7	1.2	1.3	1.1		.0159	.0225	.0160	8.2	9.4	8.1	2.1	2.3	2.2	1.4	1.7	1.5
S	.0035	S	S	3.0	S	S	1.0	S	S	.7	S		.0099	.0157	.0093	6.1	7.8	5.0	1.7	1.9	1.6	1.0	1.4	1.0
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.0022	.0043	.0019	2.5	3.4	2.1	.9	1.3	.9	.8	.8	.6

JULY 12

0.0184	0.0255	0.0179	8.7	9.1	8.4	2.1	2.6	2.2	1.7	1.8	1.5	0.0161	0.0248	0.0157	7.5	8.1	7.9	2.3	2.7	2.3	1.4	1.7	1.6
.0195	.0269	.0192	8.6	9.2	8.7	2.1	2.4	2.2	1.6	1.7	1.6	.0205	.0277	.0176	8.7	8.7	8.4	2.5	2.9	2.3	1.6	2.0	1.5
.0201	.0283	.0202	8.4	10.1	9.0	2.4	2.7	2.3	1.7	1.7	1.5	.0218	.0296	.0222	8.9	10.0	9.1	2.5	2.7	2.4	1.6	1.9	1.8
.0247	.0304	.0223	9.4	10.0	9.0	2.5	2.7	2.3	1.8	1.7	1.6	.0243	.0305	.0233	9.3	9.8	8.9	2.5	2.8	2.5	1.7	1.8	1.7
.0262	.0299	S	9.2	9.8	S	2.3	2.8	S	1.7	1.8	S	.0237	.0294	.0252	9.2	9.9	8.8	2.4	2.6	2.6	1.7	1.8	1.7
.0215	.0295	.0214	9.1	10.2	8.8	2.4	2.7	2.5	1.6	1.7	1.6	.0243	.0325	.0268	9.0	10.7	9.2	2.7	2.7	2.5	1.7	1.8	1.9
.0213	.0240	.0207	9.1	9.9	9.3	2.4	2.4	2.3	1.6	1.7	1.5	.0217	.0218	.0235	8.7	8.4	9.0	2.4	2.5	2.3	1.6	1.6	1.7
.0170	.0211	.0132	8.4	9.2	6.9	2.2	2.4	1.9	1.4	1.4	1.1	.0222	.0279	.0256	8.8	10.0	9.7	2.5	2.5	2.4	1.7	1.8	1.8
S	S	S	S	S	S	S	S	S	S	S	S	.0231	.0283	.0232	9.0	10.4	9.1	2.4	2.5	2.4	1.6	1.9	1.9
												.0182	.0244	.0199	8.0	9.9	9.1	2.2	2.5	2.2	1.7	1.8	1.7
												.0060	{.0095 .0080}	.0060	4.6	{6.1 6.1}	4.8	1.4	{1.5 1.6}	1.6	.8	{.9 1.0}	.8

JULY 13

0.0195	0.0245	S	8.2	8.7	S	2.4	2.6	S	1.6	1.7	S	0.0184	0.0315	0.0187	8.3	8.9	7.9	2.3	2.9	2.5	1.4	1.9	1.3
.0215	.0325	0.0230	9.0	9.9	8.7	2.2	2.9	2.6	1.7	2.0	1.7	.0265	.0370	.0257	8.5	9.3	8.8	2.6	3.1	2.7	1.6	1.9	1.7
.0233	.0314	.0234	8.9	9.7	9.1	2.5	3.0	2.3	1.7	1.8	1.6	.0276	.0407	.0287	8.7	9.6	9.2	2.7	3.0	2.7	1.9	2.1	2.1
.0244	.0316	.0237	9.2	9.8	8.8	2.5	2.7	2.7	1.7	1.8	1.6	.0310	.0419	.0300	9.2	10.5	9.3	2.8	3.3	2.8	1.8	2.2	1.8
.0260	.0337	.0267	9.1	10.0	9.9	2.7	2.9	2.8	1.8	1.8	1.6	.0326	.0400	.0320	8.8	9.9	9.2	2.9	3.2	2.9	1.8	1.9	2.1
.0254	.0290	.0259	9.5	9.5	9.0	2.7	2.7	2.5	1.8	1.8	1.9	.0368	.0440	.0328	9.5	10.5	9.4	3.2	3.3	2.9	2.1	2.2	1.8
.0263	.0339	.0252	9.2	10.2	9.0	2.6	2.7	2.5	1.9	2.1	1.6	.0326	.0396	.0340	9.5	10.0	9.1	2.8	3.1	2.9	1.8	2.3	1.9
.0246	.0285	.0277	9.4	10.0	9.2	2.4	2.6	2.8	1.6	1.8	1.9	.0337	.0376	.0334	9.9	10.5	9.9	2.8	3.0	3.0	1.8	2.0	2.0
.0131	.0238	.0150	7.3	9.4	7.2	2.0	2.2	2.1	1.3	1.4	1.3	.0258	.0403	.0292	9.3	10.6	9.5	2.6	3.0	2.7	1.8	2.0	2.0
												.0179	.0331	.0212	8.8	10.5	8.4	2.0	2.7	2.4	1.5	2.0	1.6

JULY 14

0.0269	0.0330	0.0263	8.8	9.6	8.8	3.0	3.0	2.5	1.7	2.0	1.9	0.0224	0.0369	0.0238	8.1	9.3	7.9	2.6	3.3	2.7	1.9	2.1	1.8
.0320	.0391	.0338	9.4	10.0	9.6	2.9	3.0	3.0	2.0	2.1	2.1	.0293	.0373	.0254	8.5	9.4	8.7	3.0	3.4	2.7	1.9	2.3	2.0
.0338	.0427	.0338	9.2	10.3	9.5	3.0	3.3	2.9	2.0	2.2	2.1	.0314	.0426	.0300	9.0	10.1	9.0	3.1	3.4	3.0	1.9	2.3	2.2
.0352	.0452	.0363	9.6	10.6	9.6	3.1	3.3	2.9	2.1	2.2	2.4	.0324	.0454	.0331	9.0	10.1	9.1	3.2	3.6	3.2	2.0	2.6	2.3
.0372	.0428	.0384	10.0	10.6	9.4	3.1	3.3	3.2	2.4	2.2	2.3	.0323	.0390	.0338	9.0	10.7	9.4	3.2	3.2	3.2	2.0	2.2	2.2
.0368	.0445	.0379	9.8	10.5	9.7	2.8	3.2	2.9	2.0	2.3	2.0	.0321	.0410	.0319	9.7	10.1	9.3	2.2	3.2	3.0	1.9	2.0	1.8
.0226	.0450	.0293	9.2	10.6	9.7	2.7	3.0	2.8	1.7	2.4	1.8	.0307	.0406	.0282	9.5	10.9	8.7	2.9	3.2	2.8	1.9	2.0	1.8
.0299	.0410	.0306	9.8	10.9	9.8	2.7	3.1	2.8	2.1	2.3	2.0	.0217	.0330	S	9.1	10.6	S	2.5	2.8	S	1.8	1.8	S
.0253	.0329	S	9.1	9.9	S	2.5	2.8	S	1.6	1.9	S	S	S	S	S	S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S	S	S	S	S												

TABLE I.—*Development of kernels of Manchuria barley from flowering to maturity in normal and clipped spikes at St. Paul, Minn., 1915*—Con.

JULY 15

Normal spikes.												Clipped spikes.											
Weight.			Length.			Lateral diameter.			Dorsoventral diameter.			Weight.			Length.			Lateral diameter.			Dorsoventral diameter.		
Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.
Gm.	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0335	0.0589	0.0320	8.6	9.5	8.6	3.0	3.6	3.1	2.1	2.4	2.1	0.0238	0.0363	0.0258	8.6	8.6	8.4	2.8	3.3	2.9	1.6	2.1	2.0
.0390	.0462	.0352	9.4	9.8	9.5	3.0	3.5	3.1	2.2	2.5	2.0	.0346	.0358	.0301	9.0	8.6	8.9	3.1	3.4	3.1	2.1	2.3	1.9
.0410	.0505	.0337	9.2	10.0	9.5	3.7	3.5	3.4	.....	2.3	2.3	.0376	.0452	.0341	9.1	9.5	9.0	3.1	3.4	3.1	2.3	2.3	2.0
.0448	.0406	.0431	9.5	9.8	9.5	3.5	3.5	3.4	2.3	2.2	2.2	.0389	.0448	.0385	9.7	9.5	9.3	3.3	3.3	3.3	2.0	2.2	2.2
.0448	.0517	.0420	9.5	10.2	9.5	3.4	3.6	3.2	2.2	2.2	2.1	.0390	.0488	.0403	9.4	10.3	9.7	3.3	3.5	3.3	2.3	2.3	2.2
.0458	.0537	.0454	9.9	10.5	9.6	3.4	3.5	3.4	2.3	2.2	2.2	.0397	.0498	.0400	9.6	10.0	9.6	3.2	3.7	3.2	2.0	2.3	2.2
.0455	.0533	.0438	10.3	10.4	9.6	3.5	3.7	3.3	2.1	2.3	2.3	.0369	.0374	.0444	9.5	10.7	[a] Dec.	3.1	3.0	3.4	2.0	2.0	2.3
S	.0462	.0384	S	11.0	10.1	S	3.2	3.2	2.4	2.3	2.0	.0358	.0496	.0365	9.9	10.5	9.6	3.1	3.4	3.0	1.8	2.3	2.1
.0342	.0423	.0292	9.5	10.8	9.6	2.9	3.2	2.9	1.9	2.2	1.8	.0279	.0390	.0324	9.5	10.8	9.9	2.7	3.2	2.8	1.9	2.2	2.0
S	S	S	S	S	S	S	S	S	S	S	S	.0098	{ .0188 .0170 }	S	6.7	{ 9.0 8.3 }	S	1.8	{ 2.4 2.2 }	S	1.0	{ 1.7 1.5 }	S

JULY 16

Dec.	0.0404	0.0287	Dec.	9.3	9.0	.....	3.4	2.9	.....	2.4	2.0	S	0.0274	S	S	7.4	S	S	3.2	S	S	2.0	S
.0325	.0444	.0343	9.3	9.7	9.1	3.0	3.6	3.1	2.0	2.4	2.1	0.0305	.0435	0.0305	9.0	9.6	8.6	3.0	3.7	3.0	1.8	2.7	1.8
.0407	.0480	.0333	9.3	10.1	9.6	3.3	3.6	3.1	2.3	2.5	2.0	.0350	.0436	.0358	9.1	10.3	9.0	3.1	3.6	3.2	2.0	2.4	2.0
.0400	.0522	.0398	10.0	10.4	9.6	3.3	3.8	3.4	2.0	2.4	2.2	.0366	.0445	.0356	9.0	9.8	9.1	3.4	3.4	3.3	2.2	2.4	2.1
.0388	.0511	.0422	9.3	11.0	10.0	3.2	3.7	3.3	2.3	2.5	2.3	.0382	.0492	.0391	9.2	10.7	9.9	3.3	3.6	3.2	2.0	2.4	2.1
.0423	.0537	.0420	9.9	10.7	10.3	3.3	3.7	3.4	2.2	2.5	2.2	.0395	.0453	.0378	9.6	10.2	9.1	2.4	3.4	3.2	2.2	2.4	2.2
.0439	.0531	.0372	9.6	11.1	9.9	3.4	3.8	3.2	2.3	2.5	1.9	.0397	.0465	.0385	10.0	10.5	9.1	3.3	3.3	3.6	2.2	2.0	2.0
.0430	.0475	.0401	9.9	10.6	10.3	3.3	3.4	3.2	2.3	2.4	2.1	.0346	.0495	.0365	9.5	11.0	9.8	3.0	3.5	3.2	2.0	2.1	2.0
.0322	.0420	.0313	9.3	10.3	9.1	2.9	3.1	2.8	1.9	2.1	1.9	.0310	.0392	.0330	9.3	10.2	9.7	3.0	3.2	3.0	1.9	2.2	1.9
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

[a] Decayed.

JULY 17

0.0292	0.0384	0.0324	8.7	9.2	9.0	3.0	3.2	3.0	2.0	2.2	2.2	0.0329	0.0480	0.0349	9.6	9.6	8.7	3.5	3.6	3.4	2.4	2.4	2.2
.0379	.0506	.0406	9.3	10.2	9.4	3.4	3.8	3.6	2.1	2.6	2.3	.0282	.0518	.0389	8.4	9.9	8.7	3.1	3.9	3.5	2.2	2.6	2.3
.0417	.0539	.0419	9.7	10.4	9.4	3.7	3.8	3.6	2.4	2.8	2.5	.0446	.0540	.0451	9.3	10.0	9.3	3.6	4.0	3.6	2.5	3.0	2.5
.0421	.0526	.0445	9.3	10.4	9.7	3.5	3.7	3.5	2.5	2.5	2.5	.0437	.0543	.0448	9.1	10.4	9.7	3.4	3.8	3.5	2.5	2.6	2.5
.0444	.0528	.0458	9.3	10.6	9.6	3.6	3.7	3.6	2.3	2.5	2.4	.0478	.0557	.0401	9.3	10.4	9.4	3.7	3.7	3.4	2.6	2.6	2.5
.0473	.0550	.0432	9.7	10.7	10.1	3.4	3.7	3.7	2.5	2.6	2.5	.0440	.0559	.0412	9.4	10.4	9.4	3.6	3.8	3.4	2.4	2.6	2.4
.0391	.0573	.0430	9.3	10.7	10.0	3.3	3.7	3.4	2.2	2.7	2.1	S	.0572	.0457	S	10.7	9.9	S	3.7	3.6	S	2.7	2.4
.0402	.0554	.0378	10.0	10.9	9.9	3.3	3.6	3.2	2.1	2.5	2.3	.0441	.0563	.0438	9.9	10.7	9.3	3.5	3.7	3.4	2.3	2.7	2.2
.0310	.0437	.0358	9.4	10.2	9.3	3.0	3.5	3.0	2.0	2.1	2.2	.0307	.0466	.0320	9.1	10.7	9.6	3.0	3.5	3.2	1.9	2.5	2.2
S	S	S	S	S	S	S	S	S	S	S	S	.....	.....	.....	.....	.....	.....	.....	.....	1.2	.....	.....	.4

JULY 19

0.0317	0.0450	0.0310	8.8	9.4	9.2	3.2	3.6	3.0	2.3	2.5	2.2	S	0.0310	0.0225	S	8.5	8.2	S	3.0	S	S	2.0	1.9
.0344	.0509	.0296	8.9	9.6	8.8	3.2	3.8	3.0	2.3	2.6	2.0	0.0298	.0401	.0276	8.5	9.0	8.7	3.2	3.3	3.0	2.2	2.2	2.0
.0412	.0552	.0378	9.3	9.4	9.0	3.6	4.0	3.3	2.4	2.9	2.3	.0356	.0457	.0325	8.7	9.5	8.7	3.4	3.8	3.2	2.1	2.6	2.3
.0446	.0543	.0457	9.2	9.4	9.3	3.5	3.8	3.6	2.4	2.7	2.4	.0381	.0458	.0400	8.5	9.3	9.0	3.5	3.5	3.4	2.3	2.5	2.4
.0508	.0553	.0472	9.6	9.6	9.9	3.8	3.9	3.6	2.5	2.6	2.4	.0421	.0535	.0443	9.5	9.9	9.7	3.5	3.9	3.5	2.5	2.7	2.3
.0545	.0637	.0493	9.7	10.6	9.7	3.8	4.0	3.5	2.6	2.7	2.5	.0457	.0593	.0487	9.2	10.2	9.8	3.5	4.0	3.8	2.4	2.7	2.4
.0530	.0664	.0554	9.7	10.6	9.9	3.7	3.9	3.8	2.5	2.8	2.6	.0439	.0553	.0490	9.3	10.2	10.2	3.6	8.8	3.7	2.3	2.4	2.3
.0456	.0576	.0498	9.6	10.8	10.2	3.5	3.7	3.6	2.3	2.7	2.5	.0472	.0578	.0445	9.6	10.6	9.9	3.7	3.8	3.6	2.3	2.5	2.5
.0498	.0635	.0429	9.7	11.0	9.7	3.6	3.9	3.2	2.3	2.7	2.3	.0408	.0592	.0485	9.2	10.2	9.7	3.4	3.9	3.8	2.3	2.4	2.4
.0375	.0731	.0349	9.2	10.2	9.0	3.2	3.6	3.2	2.1	3.9	2.1	.0385	.0553	.0410	9.2	10.4	9.7	3.3	3.7	3.4	2.2	2.7	2.3
S	S	S	S	S	S	S	S	S	S	S	S	.0333	.0547	.0385	9.8	10.5	9.8	3.2	3.7	3.4	2.0	2.6	2.3
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S	S	S	S	S	S	S	S	S	S	S	S

JULY 20

0.0388	0.0509	0.0334	9.1	9.2	8.9	3.4	3.5	3.1	2.3	2.7	2.2	0.0301	0.0458	0.0294	8.1	8.4	7.7	3.1	3.7	3.1	1.9	2.5	2.0
.0395	.0531	.0377	9.0	9.6	9.1	3.2	3.7	3.1	2.3	2.8	2.3	.0230	.0280	.0395	7.5	7.7	8.8	3.2	3.2	3.6	1.7	1.9	2.3
.0385	.0524	.0473	9.3	9.5	9.2	3.4	3.8	3.6	2.3	2.5	2.5	.0231	.0427	.0427	7.8	8.8	8.7	2.8	3.6	3.4	1.8	2.5	2.5
.0523	.0618	.0512	9.3	9.9	9.5	3.7	3.9	3.5	2.6	2.7	2.5	.0446	.0473	.0407	8.9	9.0	8.8	3.5	3.7	3.3	2.3	2.4	2.3
.0495	.0643	.0494	9.5	10.2	10.0	3.6	4.0	3.5	2.4	2.7	2.3	.0402	.0550	.0456	9.4	9.4	9.1	3.4	3.9	3.5	2.3	2.7	2.5
.0513	.0627	.0523	9.7	10.0	9.7	3.6	3.7	3.7	2.6	2.7	2.7	.0445	.0528	.0474	9.1	10.0	9.0	3.5	3.7	3.7	2.5	2.6	2.3
.0529	.0605	.0481	9.8	10.8	9.6	3.7	3.9	3.5	2.4	2.5	2.3	.0373	.0624	.0521	9.1	10.1	9.4	3.2	4.1	3.7	2.1	2.7	2.5
.0510	.0613	.0467	9.8	10.5	9.5	3.6	3.8	3.6	2.5	2.6	2.1	.0438	.0600	.0440	8.7	10.4	8.8	3.5	3.8	3.6	2.3	2.8	2.3
.0354	.0423	.0307	9.2	10.0	8.5	3.2	3.4	3.0	1.9	2.2	1.8	.0356	.0508	.0407	8.7	10.2	8.9	3.1	3.7	3.5	2.2	2.5	2.2
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

TABLE I.—*Development of kernels of Manchuria barley from flowering to maturity in normal and clipped spikes at St. Paul, Minn., 1915*—Con.

JULY 21

Normal spikes.												Clipped spikes.											
Weight.			Length.			Lateral diameter.			Dorsoventral diameter.			Weight.			Length.			Lateral diameter.			Dorsoventral diameter.		
Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.
Gm.	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0247	0.0410	a.0267	8.7	9.2	8.7	2.8	3.5	3.0	1.9	2.5	1.8	S	0.0282	S	S	7.8	S	S	3.2	S	S	2.0	S
.0348	.0505	.0368	8.9	9.2	8.7	3.2	3.8	3.4	3.2	2.7	2 5	0.0359	.0396	0.0283	8.4	8.9	8.4	3.5	3.7	3.3	2.1	2.4	2.2
.0396	.0537	.0442	9.0	9.2	9.0	3.5	3.8	3.7	2.4	2.7	2.5	.0420	.0522	.0366	8.4	9.9	9.0	3.6	3.9	3.3	2.5	2.5	2.3
.0470	.0572	.0495	9.4	9.9	9.4	3.6	4.0	3.8	2.6	2.8	2.6	.0425	.0547	.0409	9.0	9.5	8.6	3.6	3.9	3.7	2.5	2.7	2.4
.0481	.0549	.0466	9.4	10.3	9.6	3.8	3.9	3.7	2 6	2.7	2.4	.0472	.0557	.0445	8.8	10.0	9.1	3.7	3.8	3.6	2.6	2.6	2.4
.0491	.0598	.0517	9.6	10.0	9.4	3.5	4.0	3.7	2.5	2.8	2.8	.0478	.0642	.0475	9.2	10.1	9.5	3.7	4.0	3.7	2.7	2.9	2.6
.0392	.0485	.0464	9.8	10.2	9.2	3.3	3.8	3.7	2.3	2.7	2.6	.0470	.0615	.0496	9.3	10.6	9.8	3.7	3.9	3.7	2.4	2.8	2.6
.0500	.0638	.0492	9.5	11.0	9.7	3.7	3.9	3.8	2.5	2.7	2.5	.0313	.0595	.0461	8.7	10.6	9.8	3.3	4.0	3.8	2.0	2.7	2.5
.0466	.0611	.0443	9.5	11.0	9.3	3.5	3.8	3.5	2.3	2.6	2.3	.0275	.0584	.0440	8.3	9.7	8.8	2.8	3.8	3.5	1.8	2.8	2.4
.0353	S	.0242	9.3	S	9.7	3.1	S	2.8	2.0	S	L 8	S	S	S	S	S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S	S	S	S	S	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

JULY 22

0.0418	0.0493	0.0358	8.7	9.1	8.4	3.6	3.7	3.3	2.5	2.8	2.3	S	0.0410	0.0377	S	8.4	8.2	S	3.4	3.6	S	2.6	2.4
.0428	.0564	.0461	9.2	9.2	8.7	3.7	4.0	3.6	2.5	3.0	2.6	S	.0614	.0503	S	9.7	9.2	S	4.0	3.8	S	3.1	2.8
.0468	.0639	.0471	9.3	9.8	9.1	3.7	4.2	3.6	2.6	2.8	2.5	0.0518	.0497	.0516	9.0	9.1	9.0	3.7	4.0	3.8	2.8	2.7	2.8
.0554	.0672	.0485	9.6	9.8	9.3	4.0	4.1	3.8	2.7	3.0	2.7	.0547	.0681	.0517	9.4	10.2	9.2	3.8	4.3	3.9	3.0	3.2	2.7
.0480	.0655	.0547	9.6	10.2	9.5	3.7	4.0	3.9	2.5	3.0	2.8	.0584	.0664	.0566	9.0	9.2	9.2	4.1	4.2	3.8	3.0	2.9	2.8
.0597	.0682	.0588	10.0	10.6	9.4	3.9	4.0	4.0	2.8	3.0	2.9	S	.0655	.0613	S	10.2	9.8	S	4.1	4.0	S	3.0	3.0
.0462	.0625	.0533	9.2	10.7	9.8	3.7	3.9	3.7	2.6	2.7	2.6	.0630	.0665	.0636	9.9	10.2	9.2	4.0	3.9	4.1	3.0	2.8	3.0
.0507	.0622	.0500	9.9	11.1	9.9	3.8	3.9	3.8	2.5	2.7	2.7	.0537	.0691	.0567	9.8	9.5	9.3	3.5	3.9	3.7	2.8	2.8	2.8
S	.0563	.0448	S	10.2	9.2	S	3.8	3.8	S	2.7	2.3	S	.0728	S	S	10.3	SS	S	4.2	S	S	3.0	SS
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S	.....	.....	S	.....	.....	S
S	S	S	S	S	S	S	S	S	S	S	S	S	.0666	.0517	S	10.6	9.3	S	4.0	3.7	S	3.0	2.7
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S	S	S	S	S	S	S	S	S	S	S	S

JULY 23

0.0425	0.0520	0.0435	8.7	8.2	8.9	3.6	3.8	3.7	2.3	2.8	2.4	0.0345	0.0468	0.0289	8.1	9.0	8.5	3.2	3.6	3.1	2.3	2.4	2.1
.0510	.0602	.0462	9.0	9.7	8.9	3.7	4.0	3.7	2.7	2.9	2.5	.0367	.0448	.0350	3.4	9.3	8.2	3.4	3.6	3.4	2.2	2.5	2.3
.0551	.0651	.0532	9.0	9.6	9.6	3.8	4.2	3.8	2.7	2.9	2.7	.0276	.0470	.0319	7.8	9.0	8.3	3.1	3.7	3.2	2.0	2.5	2.1
.0540	.0637	.0558	9.7	9.6	9.5	3.9	4.1	3.7	2.7	3.0	2.7	.0440	.0574	.0422	9.0	9.4	8.7	3.6	3.8	3.5	2.3	2.7	2.4
.0561	.0639	.0555	9.2	10.1	9.3	3.9	4.1	3.8	2.7	2.9	2.7	.0468	.0576	.0368	10.0	9.5	8.7	3.7	3.8	3.4	2.5	2.7	2.3
.0520	.0729	.0437	9.5	10.5	8.9	3.9	4.1	3.6	2.5	3.0	2.3	.0441	.0592	S	9.2	10.0	S	3.5	3.8	S	2.5	2.6	S
.0558	.0684	.0529	9.6	10.6	9.5	3.8	4.0	3.8	2.7	2.9	2.4	.0437	.0667	.0396	9.2	10.5	8.4	3.3	4.1	3.3	2.3	2.8	2.4
.0520	.0703	.0531	9.4	10.7	9.5	3.8	3.9	3.8	2.5	3.0	2.6	.0453	.0625	.0398	9.1	10.3	8.6	3.5	3.8	3.4	2.4	2.7	2.3
.0477	.0599	S	9.5	10.5	S	3.6	3.8	S	2.4	2.6	S	.0462	.0573	.0327	9.2	10.1	8.3	3.6	3.7	3.0	2.5	2.7	2.1
S	.0258	S	S	8.6	S	S	2.9	S	S	1.7	S	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

JULY 24

.....	0.0415	0.0331	.....	9.6	9.0	.....	3.4	3.1	.....	2.3	2.2	0.0329	0.0369	0.0323	8.3	8.3	8.2	3.3	3.4	3.2	2.4	2.5	2.3
0.0352	.0485	.0391	9.0	9.4	9.0	3.3	3.7	3.6	2.2	2.6	2.5	.0401	.0586	.0404	8.4	9.2	8.6	3.7	4.0	3.7	2.4	2.8	2.5
.0389	.0544	.0393	9.2	9.6	9.2	3.5	3.7	3.5	2.3	2.8	2.2	.0407	.0548	.0350	8.7	9.4	8.2	3.6	3.8	3.4	2.5	2.8	2.4
.0403	.0535	.0497	9.0	10.2	9.3	3.6	3.6	3.9	2.5	2.7	2.7	.0468	.0594	.0420	9.0	9.6	8.9	3.6	4.0	3.5	2.5	3.0	2.4
.0462	.0524	.0490	9.6	9.3	9.2	3.6	4.1	3.5	2.5	2.6	2.6	.0501	.0576	.0537	9.3	9.5	9.0	3.7	3.9	3.6	2.5	2.6	2.6
.0474	.0613	.0538	9.4	10.5	9.4	3.5	4.0	3.8	2.5	2.8	2.7	.0552	.0642	.0417	9.0	10.0	9.1	3.8	3.9	3.5	2.7	2.9	2.5
.0487	.0620	.0529	9.6	10.7	10.0	3.6	4.0	3.6	2.5	2.8	2.6	.0548	.0682	.0487	9.4	10.2	9.5	3.8	4.0	3.4	2.5	2.8	2.5
.0475	.0576	.0487	9.6	11.0	9.6	3.7	3.7	3.6	2.6	2.6	2.4	.0474	.0669	.0509	9.2	10.6	9.5	3.4	4.1	3.7	2.5	2.9	2.5
.0418	.0567	.0446	9.4	10.8	9.4	3.3	3.7	3.4	2.4	2.7	2.0	.0390	.0481	.0359	8.7	10.1	9.2	3.3	3.5	3.3	2.1	2.5	2.4
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

JULY 26

0.0392	0.0547	0.0482	8.4	9.2	8.9	3.3	3.7	3.6	2.3	2.8	2.7	0.0348	0.0512	0.0315	8.4	8.7	8.1	3.4	3.7	3.2	2.2	2.7	2.1
.0392	.0552	.0513	8.7	9.6	8.5	3.3	3.8	3.8	2.4	2.6	2.7	.0411	.0544	.0400	8.8	9.0	8.5	3.6	3.8	3.3	2.3	2.7	2.2
.0339	.0643	.0503	8.7	9.6	9.3	3.2	3.8	3.7	2.1	2.9	2.7	.0333	.0563	.0390	8.4	9.5	8.8	3.4	4.0	3.2	2.1	2.1	2.3
.0456	.0630	.0600	9.0	9.5	9.2	3.5	4.0	3.9	2.5	2.8	2.8	S	.0506	.0456	S	9.4	8.3	S	3.0	3.5	S	2.5	2.5
.0500	.0674	.0486	9.0	9.8	8.8	3.7	3.8	3.7	2.5	2.9	2.6	.0479	.0596	.0442	9.0	9.7	9.0	3.6	3.7	3.5	2.5	2.8	2.5
S	.0494	.0472	S	10.0	9.2	S	3.6	3.5	S	2.6	2.4	.0345	.0644	.0558	9.0	9.8	9.1	3.0	4.0	3.9	2.1	2.8	2.8
.0468	.0642	.0518	9.3	10.0	9.6	3.4	3.8	3.9	2.5	2.7	2.5	.0557	.0643	.0570	9.5	9.9	9.5	3.7	4.0	4.0	2.7	3.0	2.9
.0388	.0558	S	9.1	9.9	S	3.1	3.8	S	2.1	2.5	S	.0383	.0536	.0377	8.3	9.8	8.9	3.5	3.7	3.2	2.2	2.5	2.3
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

TABLE I.—*Development of kernels of Manchuria barley from flowering to maturity in normal and clipped spikes at St. Paul, Minn., 1915*—Con.

JULY 27

Normal spikes.													Clipped spikes.											
Weight.			Length.			Lateral diameter.			Dorsoventral diameter.				Weight.			Length.			Lateral diameter.			Dorsoventral diameter.		
Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.		Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.
Gm.	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*		*Gm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0395	S	0.0410	8.7	S	8.3	3.4	S	3.5	2.3	S	2.4		0.0389	0.0486	0.0400	7.8	8.0	7.8	3.4	3.7	3.4	2.4	2.6	2.5
.0485	0.0643	.0464	8.1	9.3	8.7	3.8	4.1	3.6	2.7	3.1	2.8		.0458	.0584	S	8.0	8.5	S	3.8	4.0	4.0	2.5	3.1	S
.0513	.0646	.0523	9.2	9.0	8.9	3.8	4.1	3.7	2.7	3.0	2.8		.0483	.0643	.0502	8.4	9.1	8.5	3.8	3.9	3.7	2.5	3.1	2.6
.0506	.0693	.0532	9.1	9.9	9.1	3.7	4.2	3.5	2.6	3.0	2.6		.0452	.0688	.0535	8.5	9.3	8.7	3.6	4.2	3.7	2.5	3.2	2.7
.0527	.0717	.0554	9.2	10.1	9.0	3.6	4.0	3.6	2.7	3.1	2.8		.0442	.0703	.0576	8.6	9.6	9.2	3.5	4.0	3.7	2.5	3.1	2.9
.0568	.0758	.0639	9.8	10.3	9.4	3.8	4.1	4.1	2.7	3.0	3.0		.0366	Dec.	.0359	9.2	Dec.	8.8	3.2	.....	3.9	2.5	3.1	2.3
.0551	.0735	.0587	10.5	10.8	9.2	3.7	4.1	3.8	2.7	2.9	2.8		.0528	.0747	.0477	9.1	10.2	8.9	3.6	4.3	3.7	2.4	.....	2.5
.0569	.0735	.0601	9.3	10.6	9.6	3.7	4.1	4.0	2.6	3.2	2.7		.0514	.0753	.0578	9.3	10.2	9.0	3.8	4.0	4.0	2.6	3.1	2.5
.0432	.0458	.0341	9.1	9.5	7.8	3.5	3.7	3.3	2.2	2.2	2.1		.0484	.0568	.0426	8.9	9.5	8.5	3.6	3.8	3.5	2.3	3.2	2.7
S	S	S	S	S	S	S	S	S	S	S	S		S	S	S	S	S	S	S	S	S	2.4	2.6	2.3
																						S	S	S

JULY 28

0.0324	0.0460	S	7.9	8.2	S	3.2	3.7	S	2.3	2.7	S	S	S	S	S	S	S	S	S	S	S	S	S	.....
.0483	.0600	0.0453	8.2	8.5	8.4	3.6	4.0	3.6	2.7	3.2	2.6	0.0359	0.0422	0.0284	8.4	8.7	8.1	3.2	3.3	3.2	2.2	2.4	2.1
.0500	.0503	.0501	8.2	9.0	8.5	3.8	3.7	3.7	2.6	2.6	2.7	.0314	.0486	.0297	8.7	9.0	8.7	3.0	3.5	3.2	2.1	2.7	2.0
.0558	.0668	.0519	8.5	9.2	8.0	3.8	4.1	3.9	2.7	3.1	2.7	.0430	.0473	.0393	8.7	9.0	8.4	3.6	3.7	3.4	2.6	2.6	2.4
.0597	.0726	.0560	8.9	9.7	8.8	4.0	4.1	3.8	3.0	3.0	2.8	.0439	.0600	.0408	9.0	9.3	8.8	3.4	3.8	3.3	2.3	2.8	2.3
.0622	.0727	.0581	9.0	10.1	9.4	4.0	4.1	3.8	2.7	3.0	2.8	.0428	.0399	Dec.	9.2	9.1	Dec.	3.4	3.3	.....	2.3	2.2	.....
.0574	.0746	.0342	8.8	9.8	8.0	3.7	4.2	3.2	2.8	3.1	2.2	.0526	.0615	.0492	9.1	9.8	8.8	3.5	3.8	3.5	2.7	2.8	2.5
.0422	.0719	.0425	8.6	10.1	9.0	3.3	4.0	3.6	2.3	3.0	2.6	.0458	.0635	.0494	8.9	10.3	9.1	3.5	3.8	3.6	2.4	2.8	2.4
.0417	.0337	S	8.5	8.8	S	3.3	3.0	S	2.3	2.0	S	.0390	.0539	.0212	9.1	10.0	8.3	3.4	3.7	2.7	2.0	2.6	1.6
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

JULY 29

0.0374	0.0544	0.0387	8.1	8.7	8.0	3.4	3.8	3.3	2.4	3.0	2.5	S	0.0358	0.0243	S	8.3	7.8	S	3.1	2.8	S	2.4	1.9
S	.0604	.0477	S	8.7	8.6	S	4.0	3.6	S	3.0	2.7	0.0275	.0475	.0337	7.6	8.5	8.1	3.0	3.6	3.1	2.0	2.8	2.4
.0519	.0725	.0480	8.7	9.3	8.7	3.7	4.2	3.7	2.9	3.4	2.6	.0361	.0514	.0318	8.7	9.0	8.4	3.3	3.6	2.9	2.3	2.9	2.4
.0554	.0740	.0598	8.5	9.3	8.9	3.9	4.3	3.9	2.9	3.4	3.1	.0443	.0561	.0455	8.7	10.1	8.2	3.4	3.7	3.7	2.4	2.8	2.6
.0634	.0778	.0608	9.1	10.1	9.0	3.9	4.3	3.9	3.2	3.4	3.0	.0527	.0597	.0398	9.0	9.7	8.7	3.6	3.8	3.3	2.7	2.8	2.4
.0649	.0759	.0660	9.0	9.7	9.6	3.9	4.3	4.0	3.1	3.3	3.1	.0496	.0704	.0453	8.5	9.7	9.1	3.6	4.0	3.4	2.6	3.1	2.6
.0532	.0823	S	9.3	9.8	S	3.5	4.6	S	2.7	3.3	S	.0396	.0577	.0487	8.7	9.3	9.4	3.3	3.7	3.5	2.4	2.7	2.5
S	.0801	.0584	S	10.4	9.0	S	4.4	3.8	S	3.3	2.9	.0287	.0273	.0275	9.0	9.2	8.0	2.9	2.7	3.0	2.1	2.0	2.0
.0529	S	.0463	8.9	S	8.5	3.8	S	3.7	2.7	S	2.6	Dec.	.0421	S	Dec.	10.2	S	.....	3.1	3.3	.....	2.3	S
S	S	S	S	S	S	S	S	S	S	S	S	.0395	.0603	S	8.6	10.4	S	3.4	3.7	S	2.3	2.8	S
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S	S	S	S	S	S	S	S	S	S	S	S

JULY 30

0.0283	0.0435	S	8.0	8.0	S	3.0	3.5	S	2.2	2.7	S	S	0.0305	0.0282	S	7.4	7.6	S	3.2	3.1	S	2.3	2.1
.0356	.0490	0.0320	8.1	9.0	8.5	3.3	3.7	3.0	2.3	2.7	2.2	0.0337	.0457	.0340	8.0	8.6	8.3	3.1	3.5	3.1	2.4	2.8	2.2
.0445	.0570	.0392	9.0	9.1	7.6	3.5	3.8	3.4	2.5	3.0	2.4	.0405	.0477	.0398	8.2	8.7	8.3	3.4	3.7	3.3	2.4	2.7	2.4
.0437	.0662	.0534	8.8	9.4	8.9	3.4	4.2	3.8	2.6	3.1	2.8	.0445	.0653	.0469	8.5	9.3	8.2	3.5	4.0	3.7	2.6	3.1	2.7
.0491	.0647	.0534	8.7	9.3	8.9	3.6	4.0	3.7	2.6	2.9	2.7	.0503	.0619	.0522	8.4	9.4	8.6	3.7	3.9	3.7	2.7	2.9	2.8
.0501	.0737	.0600	8.8	9.7	9.2	3.5	4.2	3.8	2.8	3.3	3.0	.0522	.0698	.0650	9.0	9.7	9.2	3.7	4.1	3.9	2.8	3.1	3.2
.0578	.0785	.0630	9.1	10.2	9.4	3.7	4.2	4.0	2.8	3.2	2.9	.0535	.0588	.0622	8.5	9.1	9.2	3.8	4.0	3.9	2.9	3.0	3.0
.0582	.0730	.0602	9.5	10.4	9.6	3.8	4.1	3.8	2.9	3.0	3.1	.0638	.0808	.0619	8.9	10.2	9.1	4.0	4.1	3.9	3.1	3.4	3.1
.0498	.0685	.0516	9.5	10.5	9.2	3.6	4.1	3.7	2.6	2.9	2.7	S	.0675	.0541	S	10.0	8.9	S	4.0	3.7	S	3.2	2.7
.0429	.0635	S	8.8	10.2	S	3.6	3.7	S	2.4	3.0	S	S	S	S	S	S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S	S	S	S	S	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

JULY 31

0.0386	0.0467	0.0341	8.1	8.8	7.9	3.4	3.5	3.2	2.5	2.7	2.4	S	0.0355	S	S	8.8	S	S	3.1	S	S	2.3	S
.0476	.0580	.0397	8.6	9.2	8.7	3.7	3.8	3.4	2.7	3.1	2.4	0.0163	.0462	0.0258	7.6	9.0	8.1	2.6	3.5	3.0	1.6	2.5	1.9
.0412	.0635	.0521	8.1	8.8	9.0	3.4	4.1	3.7	2.6	3.1	3.0	.0211	.0480	.0330	8.2	9.3	8.2	2.8	3.6	3.1	1.8	2.7	2.3
.0519	.0780	.0613	8.7	9.5	9.3	3.6	4.3	4.0	2.8	3.4	2.9	.0362	.0575	.0401	8.6	9.6	9.0	3.2	3.7	3.1	2.3	2.7	2.2
.0460	.0741	.0608	9.0	9.6	9.0	4.0	4.3	3.8	3.0	3.2	3.0	.0259	.0594	.0516	8.3	9.9	9.0	2.8	3.6	3.6	2.1	2.8	2.8
.0594	.0804	.0606	9.2	10.0	9.3	3.8	4.3	3.7	3.0	3.3	3.1	.0468	.0594	.0462	9.1	9.8	8.8	3.4	3.8	3.5	2.6	2.9	2.7
.0592	.0692	.0612	9.5	10.5	9.6	3.7	4.0	3.9	2.9	3.0	2.9	.0483	.0670	.0503	9.0	10.0	9.0	3.5	4.0	3.6	2.5	3.0	2.8
.0525	.0719	.0589	9.0	10.6	9.6	3.6	4.1	3.7	2.7	3.1	2.8	.0402	.0624	.0560	9.1	10.2	9.2	3.2	4.0	3.8	2.5	2.8	2.9
.0330	.0617	.0498	8.7	10.5	9.3	3.0	3.8	3.6	2.1	2.8	2.7	.0418	.0588	.0489	9.5	10.2	9.2	3.3	3.7	3.5	2.4	2.8	2.6
S	S	S	S	S	S	S	S	S	S	S	S	.0351	.0464	S	9.1	9.8	S	3.2	3.5	S	2.2	2.4	S
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S	S	S	S	S	S	S	S	S	S	S	S

TABLE I.—*Development of kernels of Manchuria barley from flowering to maturity in normal and clipped spikes at St. Paul, Minn., 1915*—Con.

AUGUST 2

Normal spikes.																					
Weight.			Length.			Lateral diameter.			Dorsoventral diameter.			Clipped spikes.										
												Weight.			Length.			Lateral diameter.			Dorsoventral diameter.		
Lateral kernel.	Central kernel.	Lateral kernel.	Lateral. kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral kernel.	Central kernel.	Lateral kernel.	Lateral ker. kernel.	Central kernel.	Lateral kernel.	Lateral kernel-	Central kernel.	Lateral kernel.
Gm.	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
S	0.0505	0.0350	S	8.8	8.0	S	3.6	3.2	S	2.9	2.5	S	S	S	S	S	S	S	S	S	S	S	S
0.0510	.0669	.0587	8.5	9.1	8.3	3.7	4.2	3.9	2.8	3.3	3.1	0.0375	0.0477	0.0357	8.6	8.7	8.6	3.3	3.7	3.2	2.5	2.9	2.4
.0545	.0686	.0590	8.5	9.1	8.9	3.8	4.1	3.7	3.0	3.3	3.1	.0409	S	.0382	8.6	S	8.4	3.5	S	3.4	2.4	S	2.5
.0477	.0755	.0626	8.3	9.6	8.9	3.4	4.5	4.0	2.7	3.3	3.1	.0556	.0627	.0448	8.8	9.8	8.8	3.7	4.0	3.5	3.0	3.0	2.5
.0681	.0857	.0636	9.2	10.2	9.4	4.2	4.5	4.0	3.2	3.5	3.1	.0589	.0626	.0465	9.0	9.8	8.6	3.9	3.8	3.5	2.9	3.0	2.7
.0700	.0883	.0691	9.1	10.2	9.3	4.1	4.4	4.0	3.3	3.4	3.1	.0595	.0625	.0544	9.0	9.7	8.8	3.9	4.0	3.7	2.9	2.9	2.8
.0612	.0831	.0653	9.7	9.8	9.5	3.9	4.3	4.0	3.0	3.3	3.1	.0454	.0855	.0690	8.8	9.9	9.6	3.4	4.4	4.1	2.6	3.5	3.1
.0578	.0845	.0577	8.9	10.6	9.0	3.8	4.2	3.7	2.9	3.4	2.9	.0750	.0794	.0673	9.5	10.2	9.6	4.3	4.2	4.0	3.3	3.3	3.3
.0629	.0708	.0606	9.0	10.1	9.2	3.8	4.1	3.9	3.0	3.0	3.3	.0686	.0846	.0739	9.6	10.6	9.6	4.2	4.4	4.2	3.1	3.3	3.2
S	S	S	S	S	S	S	S	S	S	S	S	.0712	.0892	.0742	9.6	10.5	9.6	4.1	4.5	4.3	3.2	3.4	3.3
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.0623	.0337	.0626	9.5	10.5	9.6	3.8	2.9	4.0	2.7	2.2	2.9
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S	S	S	S	S	S	S	S	S	S	S	S

AUGUST 4

0.0315	0.0611	0.0459	7.7	8.7	8.5	3.1	4.0	3.6	2.1	3.0	2.7	0.0190	0.0315	0.0212	7.8	8.6	7.6	2.8	3.1	2.5	1.6	2.3	1.9
.0516	.0647	.0486	8.4	9.3	7.8	3.8	4.0	3.7	2.9	3.1	2.8	.0289	.0347	.0308	8.2	8.8	8.2	3.0	3.2	3.2	2.0	2.3	2.1
.0549	.0706	.0528	8.6	9.2	8.7	3.8	4.2	3.9	2.9	3.3	2.8	.0274	.0408	.0346	8.8	8.8	8.4	3.1	3.5	3.4	2.1	2.3	2.3
.0515	.0705	.0580	8.9	9.8	9.0	3.8	4.2	3.9	2.7	3.2	3.0	.0372	.0463	Missing	9.0	9.2	.....	3.2	3.7	.....	2.3	2.5	.....
.0643	.0776	.0409	9.1	9.5	8.8	4.0	4.3	3.4	3.0	3.4	2.4	.0349	.0455	.0402	9.0	9.3	8.9	3	3.4	3.3	2.3	2.6	2.3
.0622	.0756	.0417	9.2	10.2	9.3	4.0	4.4	3.4	2.9	3.2	2.4	.0371	.0313	.0386	9.1	9.6	9.4	3.2	3.1	3.1	2.3	2.2	2.5
.0656	.0850	.0540	9.2	10.4	9.1	4.0	4.4	3.8	3.1	3.4	2.7	S	.0463	.0425	S	10.0	9.3	S	3.4	3.5	S	2.3	2.5
.0650	.0815	.0597	9.3	10.5	9.0	4.1	4.4	4.0	3.1	3.3	2.8	.0261	.0431	.0454	8.5	10.3	9.5	3.0	3.4	3.5	2.0	2.3	2.3
S	.0705	.0464	S	10	8.8	S	4.0	3.5	S	3.1	2.6	.0345	.0442	.0311	9.4	9.8	9.4	3.1	3.4	2.8	2.2	2.3	1.9
S	S	S	S	S	S	S	S	S	S	S	S	.0155	.0273	.0176	7.8	9.4	7.9	2.6	2.8	2.6	1.4	1.7	1.6
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	S	S	S	S	S	S	S	S	S	S	S	S

AUGUST 5

0. 0457	0. 0620	0. 0402	7. 9	9. 0	7. 8	3. 7	3. 9	3. 5	2. 8	3. 1	2. 5	0. 0298	0. 0446	0. 0317	8. 1	8. 9	7. 9	3. 0	3. 4	3. 1	2. 3	2. 8	2. 2
. 0550	. 0713	. 0477	8. 6	9. 0	8. 2	3. 8	4. 3	3. 5	3. 0	3. 5	2. 8	. 0310	. 0490	. 0355	7. 8	8. 7	7. 9	3. 2	3. 7	3. 2	2. 3	2. 9	2. 4
. 0596	. 0777	. 0581	8. 8	9. 6	8. 9	3. 8	4. 4	3. 8	3. 1	3. 4	3. 0	. 0344	. 0572	. 0392	8. 5	9. 3	8. 4	3. 2	3. 9	3. 2	2. 3	2. 9	2. 5
. 0636	. 0800	. 0664	9. 0	10. 2	8. 8	3. 9	4. 2	3. 8	3. 1	3. 3	3. 2	. 0410	. 580	. 0431	8. 3	9. 1	8. 1	3. 3	3. 7	3. 4	2. 6	2. 9	2. 6
. 0665	. 0840	. 0665	9. 2	10	9. 1	3. 9	4. 2	4. 0	3. 2	3. 4	3. 1	. 0412	. 0427	. 0319	8. 4	9. 5	8. 2	3. 4	3. 4	3. 1	2. 4	2. 5	2. 4
. 0652	. 0870	. 0648	8. 9	10. 2	9. 1	3. 8	4. 2	3. 8	3. 1	3. 5	3. 2	. 0352	. 0652	. 0419	8. 7	9. 9	8. 2	3. 0	3. 9	3. 5	2. 2	2. 9	2. 6
. 0477	. 0862	. 0567	8. 8	10. 3	9. 1	3. 5	4. 2	3. 6	2. 6	3. 5	2. 8	S	. 0611	. 0402	S	10.	8. 9	S	3. 7	3. 4	S	2. 8	2. 3
. 0567	. 0685	S	9. 1	10. 5	S	3. 7	4. 0	S	2. 9	2. 9	S	S	S	S	S	10. 2	9. 2	S	S	S	S	S	S
S	S	S			S	S	S	S	S	S	S	. 0512	. 0772	. 0618	8. 7	S	S	3. 7	4. 1	3. 8	2. 7	3. 2	2. 8
												S	S	S	S			S	S	S	S	S	S

AUGUST 6

0. 0263	0. 0343	S	7. 6	9. 0	S	2. 8	3. 2	S	2. 2	2. 5	S	0. 0255	0. 0358	0. 0247	8. 0	8. 2	7. 5	2. 8	3. 2	2. 8	2. 2	2. 5	2. 1
. 0315	. 0403	0. 0309	8. 1	8. 6	7. 9	3. 0	3. 5	3. 1	2. 3	2. 7	2. 4	. 0257	. 0343	. 0195	7. 9	9. 0	7. 6	2. 8	3. 2	2. 6	2. 0	2. 3	1. 8
. 0398	. 0452	. 0382	8. 3	8. 6	8. 2	3. 3	3. 6	3. 3	2. 5	2. 8	2. 5	. 0302	. 0478	. 0331	8. 0	9. 1	7. 8	3. 0	3. 4	3. 0	2. 3	2. 7	2. 3
. 0416	. 0556	. 0380	8. 7	9. 5	8. 3	3. 4	3. 8	3. 2	2. 6	2. 9	2. 6	. 0376	. 0516	. 0357	8. 4	9. 4	8. 3	3. 2	3. 5	3. 2	2. 4	2. 8	2. 4
. 0440	. 0606	. 0425	8. 6	9. 7	8. 8	3. 5	3. 8	3. 4	2. 5	3. 0	2. 5	. 0297	. 0515	. 0421	8. 3	9. 2	8. 2	2. 9	3. 3	3. 4	2. 3	2. 8	2. 5
. 0482	. 0583	. 0481	9. 0	10	8. 4	3. 6	3. 7	3. 5	2. 6	2. 9	2. 8	. 0423	. 0682	. 0417	8. 4	9. 7	9. 0	3. 2	3. 7	3. 3	2. 7	3. 0	2. 5
. 0479	S	. 0426	8. 8	S	8. 6	3. 6	S	3. 4	2. 5	S	2. 6	. 0426	. 0659	. 0594	8. 8	9. 9	8. 8	3. 3	3. 8	3. 7	2. 5	2. 9	2. 7
. 0402	. 0537	S	9. 1	9. 7	S	3. 2	3. 4	S	2. 4	2. 6	S	. 0393	. 0435	. 0548	8. 7	9. 6	9. 0	3. 1	3. 2	3. 7	2. 3	2. 5	2. 8
. 0354	. 0454	. 0275	8. 5	9. 7	7. 8	3. 0	3. 3	2. 8	2. 1	2. 5	1. 9	. 0352	. 0670	. 0384	8. 4	9. 8	8. 5	3. 1	3. 9	3. 2	2. 1	2. 9	2. 2
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

AUGUST 7

0. 0298	0. 0362	0. 0287	8. 0	7. 8	7. 7	3. 0	3. 3	3. 3	2. 4	2. 5	2. 3	0. 0191	0. 0328	0. 0215	7. 9	8. 7	7. 6	2. 5	3. 2	2. 7	1. 9	2. 4	2. 0
. 0280	. 0435	. 0360	8. 4	8. 5	8. 0	2. 8	3. 6	3. 2	2. 3	2. 8	2. 6	. 0283	. 0379	. 0286	8. 1	8. 7	8. 1	2. 9	3. 3	2. 9	2. 3	2. 5	2. 2
. 0429	. 0457	. 0419	8. 7	9. 1	8. 6	3. 3	3. 6	3. 3	2. 7	2. 8	2. 6	a Dis.	. 0230	.....	Dis.	9. 0	Dis.	.....	2. 8	.....	.....	2. 1	.....
. 0443	. 0582	. 0416	8. 5	9. 5	8. 5	3. 4	3. 9	3. 4	2. 7	3. 0	2. 7	. 0238	. 0232	Dis.	8. 2	8. 9	Dis.	2. 7	2. 8	.....	2. 1	1. 9	.....
. 0491	. 0503	S	8. 9	9. 7	S	3. 4	3. 5	S	2. 7	2. 7	S	. 0374	. 0391	. 0340	8. 7	9. 3	8. 7	3. 2	4. 2	3. 2	2. 5	2. 5	2. 4
. 0538	. 0702	. 0498	8. 8	9. 6	8. 5	3. 7	4. 0	3. 5	2. 8	3. 0	2. 8	. 0350	S	. 0377	8. 6	S	9. 1	3. 2	S	3. 3	2. 4	S	2. 5
. 0494	. 0698	. 0476	9. 0	9. 6	8. 8	3. 5	4. 0	3. 5	2. 6	3. 0	2. 7	. 0372	. 0500	. 0347	8. 4	9. 7	8. 1	3. 2	3. 5	3. 2	2. 5	2. 7	2. 4
. 0477	. 0450	. 0429	9. 3	9. 6	8. 8	3. 5	3. 4	3. 4	2. 5	2. 7	2. 6	. 0347	. 0436	. 0338	8. 7	9. 9	8. 9	3. 0	3. 1	3. 1	2. 3	2. 5	2. 3
S	S	S	S	S	S	S	S	S	S	S	S	. 0351	. 0476	. 0351	8. 5	9. 6	8. 4	3. 1	3. 4	3. 0	2. 3	2. 7	2. 3
												S	S	S	S	S	S	S	S	S	S	S	S

a Diseased.

The use of a single spike and the great change of climatic conditions from day to day in Minnesota resulted in a much less uniform trend to the results than was the case with the Hannchen barley previously reported.[1] A sample should consist of more than one spike; but, entirely aside from the smallness of the sample, Minnesota is not a desirable place to make a study of this kind. There are many cold, dark days in which little growth occurs, while frequent storms break the culms and cause lodging. The lodging was so bad during the latter part of the experiment that many of the culms started to decay near the base. The resultant irregularities are quite apparent in Table II, where the data presented in Table I are summarized.

TABLE II.—*Average wet weight, length, lateral diameter, and dorsoventral diameter of kernels from normal and clipped spikes of Manchuria barley at St. Paul, Minn., in 1915*

NORMAL SPIKES

Date.	Wet weight.				Length.				Lateral diameter.				Dorsoventral diameter.			
	Lateral kernel.	Central kernel.	Lateral kernel.	Average.	Lateral kernel.	Central kernel.	Lateral kernel.	Average.	Lateral kernel.	Central kernel.	Lateral kernel.	Average.	Lateral kernel.	Central kernel.	Lateral kernel.	Average.
	Mgm.	*Mgm.*	*Mgm.*	*Mgm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
July 1	0.9	1.2	0.9	1.0	1.9	2.1	1.8	1.9	0.7	0.7	0.7	0.7	.....	.....	.....	.....
2	1.1	1.7	1.2	1.3	2.0	2.3	2.0	2.1	.7	.8	.7	.7	.....	.....	.....	.....
3	1.3	1.8	1.2	1.4	2.0	2.1	1.9	2.0	.7	.8	.7	.7	.....	.....	.....	.....
5	1.7	2.7	1.8	2.1	2.2	2.5	2.2	2.3	.8	1.0	.9	.9	0.6	0.8	0.6	0.7
7	6.3	10.2	5.7	7.4	4.2	5.2	3.8	4.4	1.5	1.7	1.4	1.5	1.0	1.1	1.0	1.0
8	6.7	8.2	5.9	6.9	4.3	4.6	4.0	4.3	1.5	1.6	1.5	1.5	1.0	1.1	1.0	1.0
9	7.0	9.3	7.1	7.8	4.3	5.0	4.4	4.6	1.6	1.7	1.7	1.7	1.1	1.2	1.1	1.1
10	10.7	14.7	10.3	11.9	5.9	7.2	5.8	6.3	1.8	2.1	1.8	1.9	1.2	1.3	1.1	1.2
11	17.3	20.1	16.2	17.9	8.2	8.5	7.8	8.2	2.3	2.2	2.2	2.2	1.5	1.5	1.5	1.5
12	21.1	27.0	19.3	22.5	8.9	9.7	8.6	9.1	2.3	2.6	2.2	2.4	1.6	1.7	1.5	1.6
13	22.7	29.9	23.8	25.5	8.9	9.7	8.9	9.2	2.4	2.7	2.5	2.5	1.7	1.8	1.7	1.7
14	31.1	40.7	33.3	35.0	9.4	10.3	9.5	9.7	2.9	3.1	2.9	3.0	2.0	2.2	2.1	2.1
15	41.1	49.3	38.1	42.8	9.5	10.2	9.5	9.7	3.3	3.5	3.2	3.3	2.2	2.3	2.1	2.2
16	39.2	48.0	36.5	41.2	9.6	10.0	9.7	9.8	3.2	3.6	3.2	3.3	2.2	2.4	2.1	2.2
17	39.2	51.1	40.6	43.6	9.4	10.4	9.6	9.8	3.4	3.6	3.4	3.5	2.2	2.5	2.3	2.3
19	44.3	58.5	42.4	48.4	9.4	10.1	9.5	9.7	3.5	3.8	3.4	3.6	2.4	2.8	2.3	2.5
20	45.5	56.6	44.1	48.7	9.4	10.0	9.3	9.6	3.5	3.7	3.4	3.5	2.4	2.6	2.3	2.4
21	41.4	54.5	42.0	46.0	9.3	10.0	9.3	9.5	3.4	3.8	3.5	3.6	2.4	2.7	2.4	2.5
22	48.9	61.3	48.8	53.0	9.4	10.1	9.3	9.6	3.8	4.0	3.7	3.8	2.6	2.9	2.6	2.7
23	51.8	60.2	50.5	54.2	9.3	9.8	9.3	9.5	3.8	3.9	3.7	3.8	2.6	2.8	2.5	2.6
24	44.0	54.2	45.6	47.9	9.4	10.0	9.3	9.6	3.5	3.8	3.6	3.6	2.4	2.7	2.4	2.5
26	41.9	59.3	51.1	50.8	8.9	9.7	9.1	9.2	3.4	3.8	3.7	3.6	2.3	2.7	2.6	2.5
27	50.5	67.3	51.7	56.5	9.2	9.9	8.9	9.3	3.7	4.1	3.7	3.8	2.6	2.9	2.7	2.7
28	50.0	61.0	48.3	53.1	8.5	9.3	8.6	8.8	3.6	3.9	3.7	3.7	2.6	2.9	2.6	2.7
29	54.2	72.2	53.2	59.9	8.8	9.5	8.8	9.0	3.7	4.2	3.7	3.9	2.8	3.3	2.8	3.0
30	46.0	63.8	51.6	53.8	8.8	9.6	8.9	9.1	3.5	4.0	3.7	3.7	2.6	3.0	2.7	2.8
31	49.7	67.1	53.2	56.6	8.8	9.7	9.1	9.2	3.6	4.0	3.7	3.8	2.7	3.1	2.8	2.9
Aug. 2	59.2	74.9	59.1	64.4	8.9	9.7	8.9	9.2	3.8	4.2	3.8	3.9	3.0	3.3	3.0	3.1
4	55.8	73.0	49.8	59.5	8.8	9.7	8.8	9.1	3.8	4.2	3.7	3.9	2.8	3.2	2.7	2.9
5	57.5	77.1	57.2	63.9	8.8	9.9	8.7	9.1	3.8	4.2	3.7	3.9	3.0	3.3	2.9	3.1
6	39.4	49.2	38.3	42.3	8.5	9.4	8.3	8.7	3.3	3.5	3.2	3.3	2.4	2.7	2.5	2.5
7	43.1	52.4	41.2	45.6	8.7	9.2	8.4	8.8	3.3	3.7	3.4	3.5	2.6	2.8	2.6	2.7

[1] HARLAN, Harry V., OP. CIT.

TABLE II.—*Average net weight, length, lateral diameter, and dorsoventral diameter of kernels from normal and clipped spikes of Manchuria barley at St. Paul, Minn., in 1915*—Continued

CLIPPED SPIKES

Date.	Wet weight.				Length.				Lateral diameter.				Dorsoventral diameter.			
	Lateral kernel.	Central kernel.	Lateral kernel.	Average.	Lateral kernel.	Central kernel.	Lateral kernel.	Average.	Lateral kernel.	Central kernel.	Lateral kernel.	Average.	Lateral kernel.	Central kernel.	Lateral kernel.	Average.
	Mgm.	*Mgm.*	*Mgm.*	*Mgm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
July 2	1.5	2.3	1.5	1.8	2.2	2.5	2.3	2.3	0.8	0.9	0.7	0.8	.....	.....	.....	.....
3	1.4	2.1	1.5	1.7	2.1	2.4	2.1	2.2	.7	.8	.7	.7	.....	.....	.....	.....
5	2.1	3.2	2.0	2.4	2.4	2.6	2.3	2.4	1.1	1.2	1.1	1.1	0.8	0.8	0.8	0.8
7	5.6	7.9	5.6	6.4	3.8	4.5	3.8	4.0	1.4	1.6	1.4	1.5	1.0	1.1	1.0	1.0
8	4.0	5.6	3.9	4.5	3.3	3.7	3.3	3.4	1.3	1.4	1.3	1.3	.9	1.0	.9	.9
9	8.5	11.4	7.8	9.2	5.2	6.1	4.8	5.4	1.6	1.8	1.6	1.7	1.0	1.2	1.0	1.1
10	10.8	15.8	10.1	12.2	6.4	7.7	6.2	6.8	1.8	2.3	1.8	2.0	1.2	1.4	1.2	1.3
11	14.8	18.4	13.6	15.6	7.3	8.0	7.0	7.4	2.0	2.2	1.9	2.0	1.4	1.5	1.3	1.4
12	20.2	24.5	20.8	21.8	8.3	9.0	8.5	8.6	2.3	2.5	2.3	2.4	1.6	1.7	1.6	1.6
13	28.3	38.6	28.6	31.8	9.1	10.0	9.1	9.4	2.7	3.1	2.8	2.9	1.8	2.1	1.8	1.9
14	29.0	39.5	29.5	32.7	9.0	10.2	8.9	9.4	2.8	3.3	2.9	3.0	1.9	2.2	2.0	2.0
15	32.4	38.4	35.8	35.5	9.1	9.6	9.3	9.3	3.0	3.2	3.1	3.1	1.9	2.1	2.1	2.0
16	35.6	43.2	35.9	38.2	9.3	10.0	9.3	9.5	3.2	3.4	3.2	3.3	2.0	2.3	2.0	2.1
17	39.5	53.3	40.7	44.5	9.3	10.3	9.3	9.6	3.4	3.7	3.2	3.4	2.4	2.6	2.2	2.4
19	39.5	50.7	39.7	43.3	9.2	9.8	9.4	9.5	3.4	3.7	3.5	3.5	2.3	2.5	2.3	2.4
20	35.8	49.4	42.5	42.6	8.6	9.3	8.8	8.9	3.3	3.7	3.5	3.5	2.1	2.5	2.3	2.3
21	40.2	52.7	42.2	45.0	8.8	9.7	9.1	9.2	3.5	3.8	3.6	3.6	2.3	2.6	2.4	2.4
22	56.3	62.7	53.5	57.5	9.4	9.7	9.2	9.4	3.8	4.0	3.8	3.9	2.9	2.9	2.8	2.9
23	41.0	55.5	35.9	44.1	8.9	9.7	8.5	9.0	3.4	3.8	3.3	3.5	2.3	2.6	2.3	2.4
24	45.2	57.2	42.3	48.2	8.9	9.7	8.9	9.2	3.6	3.8	3.5	3.6	2.5	2.8	2.5	2.6
26	40.8	56.8	43.9	47.2	8.8	9.5	8.8	9.0	3.5	3.7	3.5	3.6	2.3	2.6	2.5	2.5
27	45.7	64.7	48.2	52.9	8.6	9.3	8.7	8.9	3.6	4.0	3.7	3.8	2.5	3.0	2.6	2.7
28	41.8	52.1	36.9	43.6	8.9	9.4	8.6	9.0	3.4	3.6	3.3	3.4	2.3	2.6	2.2	2.4
29	39.8	50.8	37.1	42.6	8.6	9.4	8.5	8.8	3.3	3.5	3.2	3.3	2.4	2.7	2.4	2.5
30	48.4	58.7	49.4	52.2	8.5	9.2	8.6	8.8	3.6	3.8	3.6	3.7	2.7	2.9	2.7	2.8
31	34.6	54.1	44.0	44.2	8.7	9.7	8.8	9.1	3.1	3.7	3.4	3.4	2.2	2.7	2.5	2.5
Aug. 2	57.5	67.5	56.7	60.6	9.1	10.0	9.1	9.4	3.8	4.0	3.8	3.9	2.9	3.1	2.9	3.0
4	29.0	39.1	33.6	33.9	8.6	9.4	8.7	8.9	3.0	3.3	3.1	3.1	2.0	2.3	2.2	2.2
5	37.7	56.9	40.7	45.1	8.4	9.5	8.4	8.8	3.3	3.7	3.3	3.4	2.4	2.9	2.5	2.6
6	34.2	51.7	38.8	41.6	8.3	9.3	8.3	8.6	3.0	3.5	3.2	3.2	2.3	2.7	2.4	2.5
7	31.3	37.2	32.2	33.6	8.4	9.2	8.4	8.7	3.0	3.3	3.1	3.1	2.3	2.4	2.3	2.3

In both the tables and the figures it is apparent that fertilization did not occur until about July 5; therefore, the measurements and weights before that date are of the ovary. Six-rowed barleys do not flower so uniformly as 2-rowed barleys. The central florets flower before the lateral ones. For this reason the curve of growth is less abrupt at the beginning than is the case with the 2-rowed varieties. Even with the prolonged period of flowering the length increases very rapidly after fertilization, as may be seen in figure 1.

The effect of the clipping is evident in both figure 1 and figure 2. Although there is little difference in length near maturity, the lateral diameters and the dorsoventral diameters of the kernels from clipped spikes are noticeably smaller than those of normal spikes. The difference is even more conspicuous in the wet weights per kernel. The question of mechanical injury from clipping is answered by a study of the growth by days. There is no such injury. For two weeks after clipping, the kernels in the clipped spikes develop as rapidly in size and weight as do those in

normal spikes. The graphs of wet weights per kernel coincide essentially until the fourteenth day after the experiment started. If there were a mechanical injury it would probably most seriously affect the kernel immediately after the injury.

After the fourteenth day the kernels in the normal spikes increase more rapidly in weight and size than do those in the clipped spikes. On only two days after July 14 do the clipped spikes exceed the normal ones, and these excesses are unquestionably due to the error of sampling which comes from the use of a single spike for this purpose.

The difference in rate of development begins to be noticeable about the time that the growth in length is completed. This coincides roughly with the beginning of the period of rapid starch infiltration. Whether

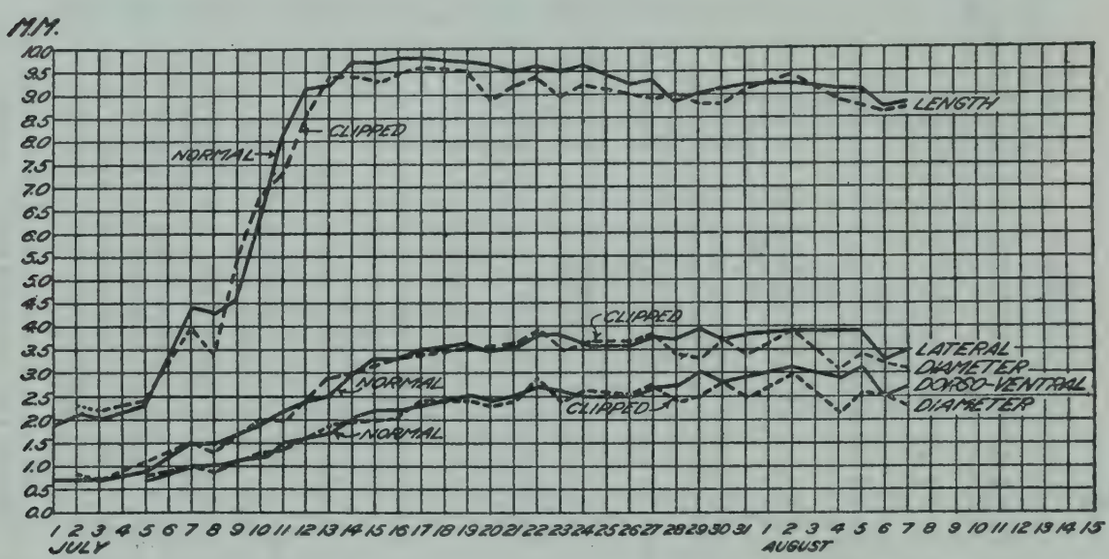

FIG. 1.—Graph showing growth in length, lateral diameter, and dorsoventral diameter of kernels of Manchuria barley in normal and clipped spikes.

this indicates a loss, in the clipped spikes, of the photosynthetic products of the awn, as well as lower transpiration, as indicated by Zoebl and Mikosch, is not shown by the data. At first the difference is more apparent in the weights than in the dimensions. After the twenty-seventh day from the beginning of the experiment the lateral diameter of the kernels from the clipped spikes begins to decrease. This is probably due to the rate of loss of water in maturation, which here exceeds the rate of deposit of dry matter. In the normal spikes the two changes about balance each other so far as their effect on the lateral diameter is concerned. The dorsoventral diameter continues to increase until full maturity in the normal spikes, while it is slightly less than maintained by the clipped spikes in the latter days. At the very last the kernels in the clipped spikes ripen faster than those in the normal spikes. This is apparent in both figure 2 and figure 3.

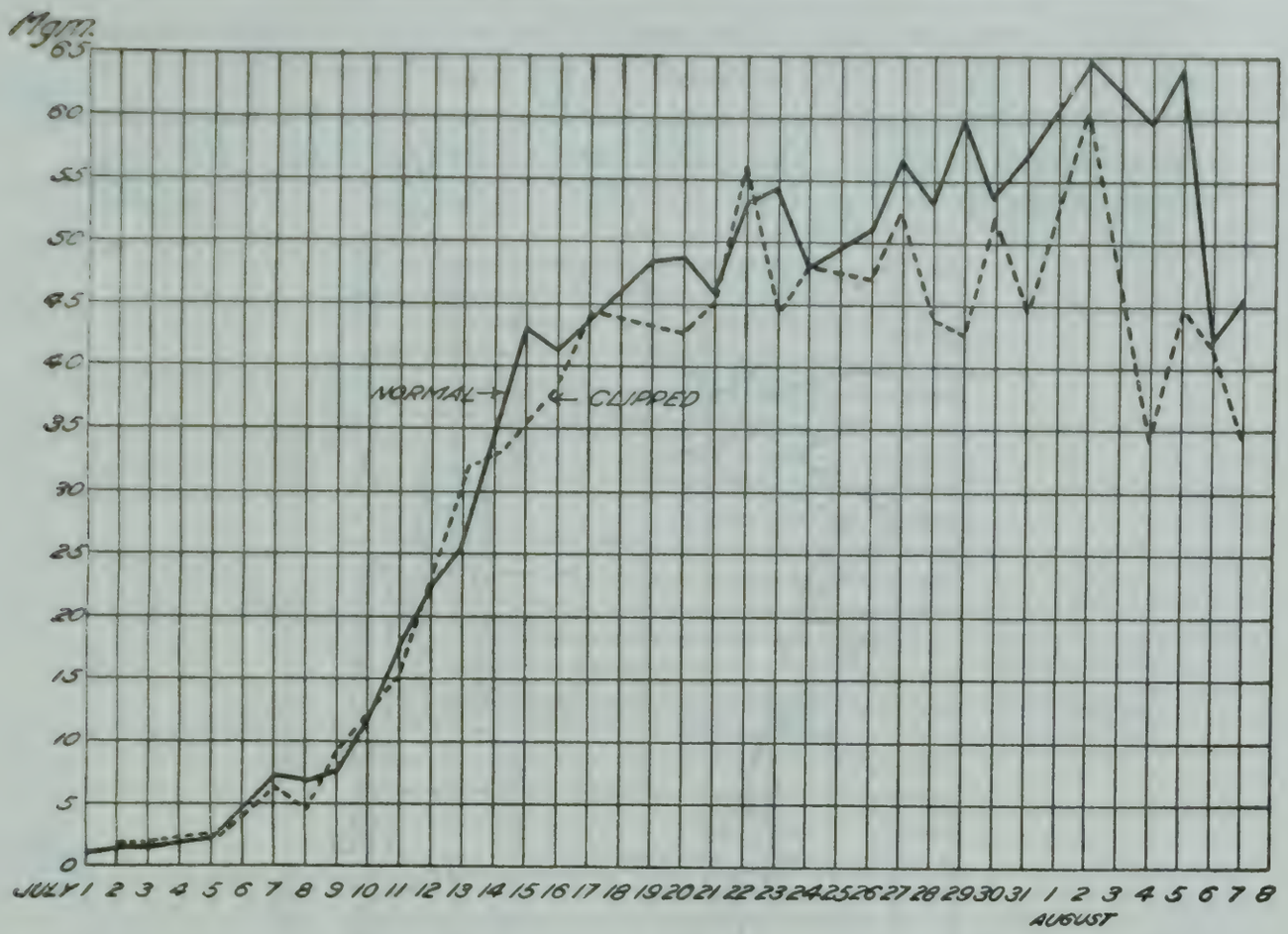

FIG. 2.—Graph showing wet weight of kernels of Manchuria barley from normal and clipped spikes.

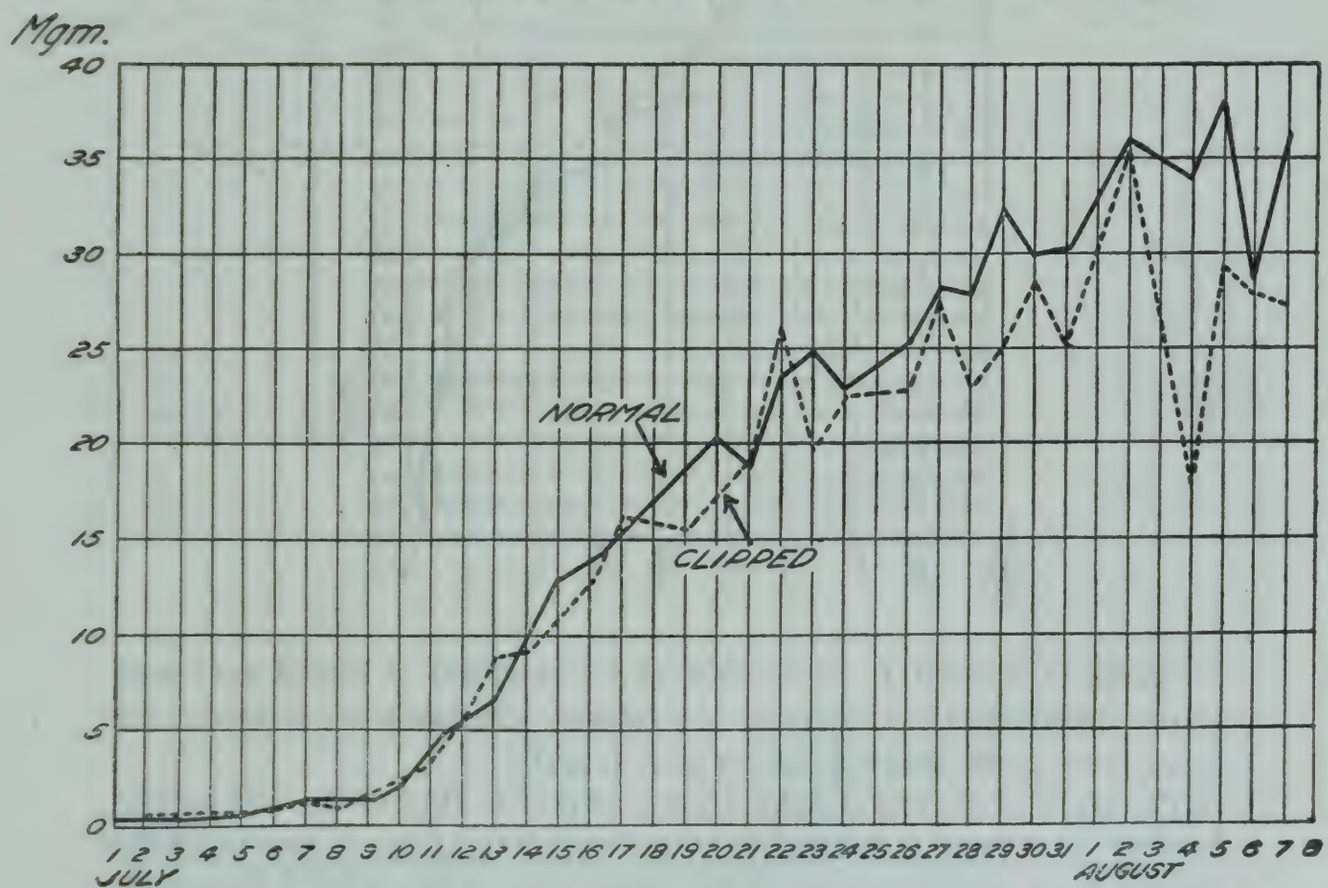

FIG. 3.—Graph showing dry matter in kernels of Manchuria barley from normal and clipped spikes.

The nitrogen, ash, and water were determined in all samples. Inasmuch as the glumes were removed, the difference between the total of these substances and the dry weight would approximate the sum of the carbohydrates and fats. This calculation has not been made. Its trend would be similar to that of the dry weight. The results of the analyses

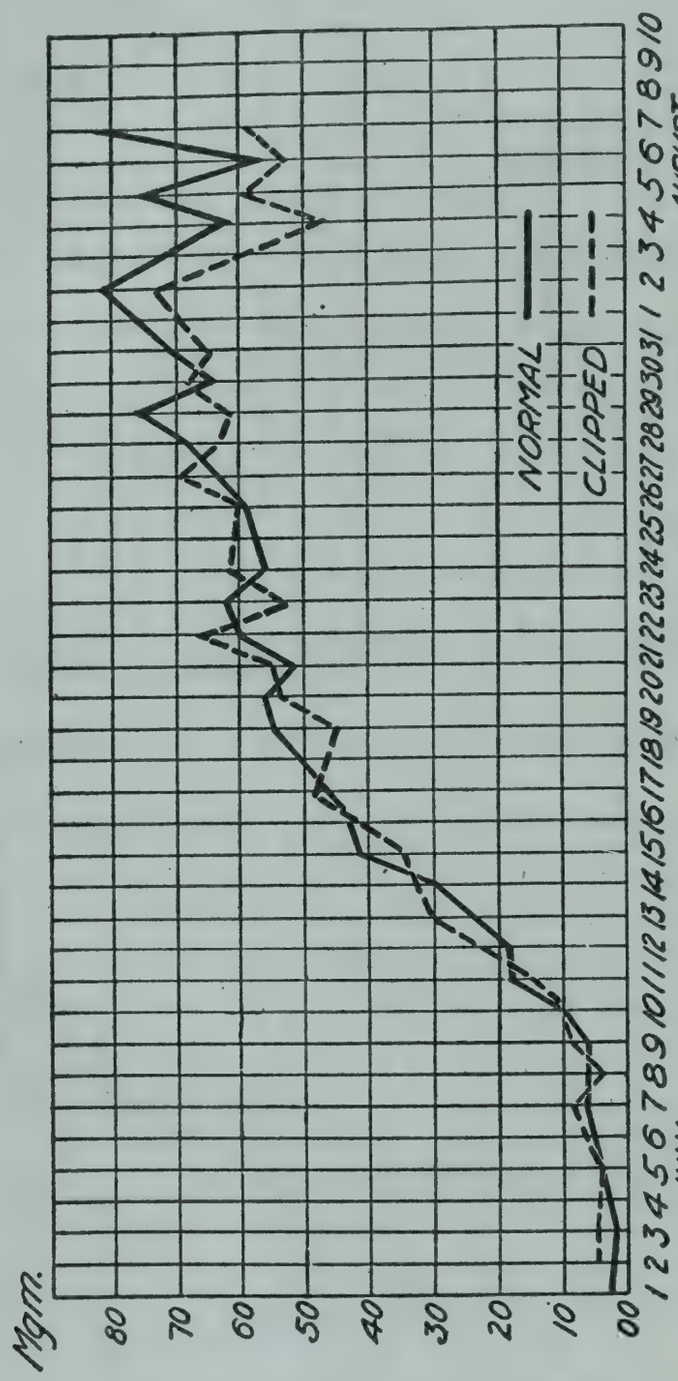

FIG. 4.—Graph showing total ash in kernels of Manchuria barley from normal and clipped spikes.

are given in Table III. The cause of the addition or loss of each substance determined is evident in the tables. Comparisons, however, are much more easily made in figures 3, 4, 5, and 6.

The graph of the dry weight is quite similar to that of the wet weight. In each case there is a marked reduction of the rate of growth of the kernels from clipped spikes in the latter half of the period of growth.

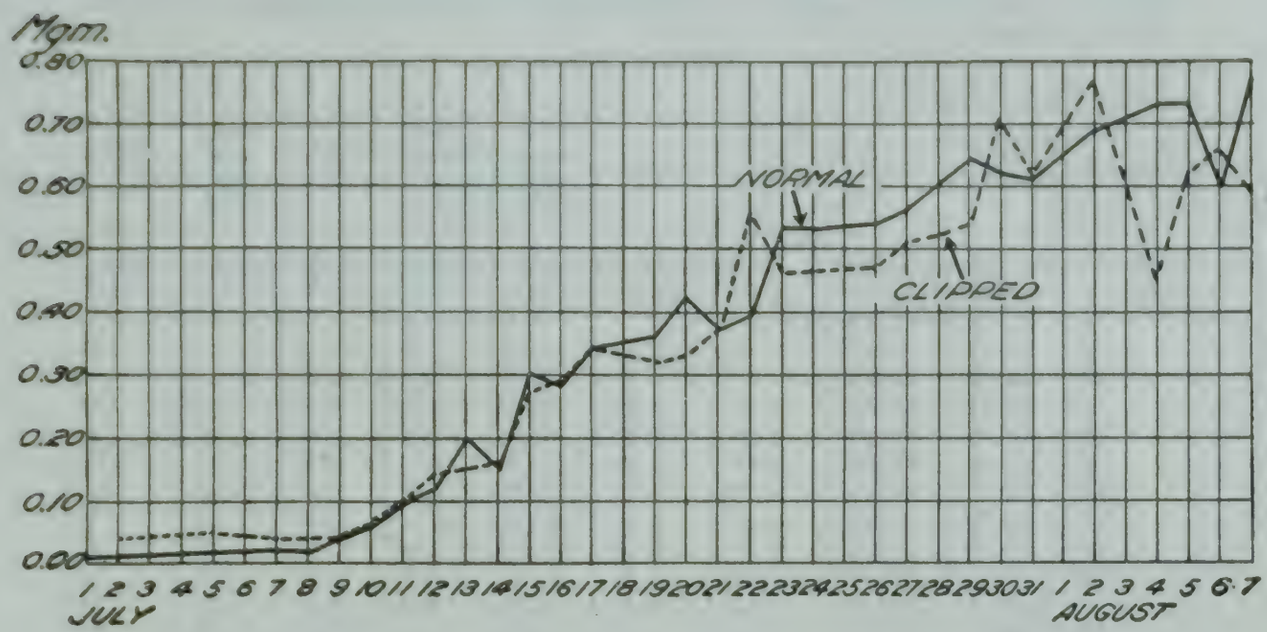

FIG. 5.—Graph showing total nitrogen in kernels of Manchuria barley from normal and clipped spikes.

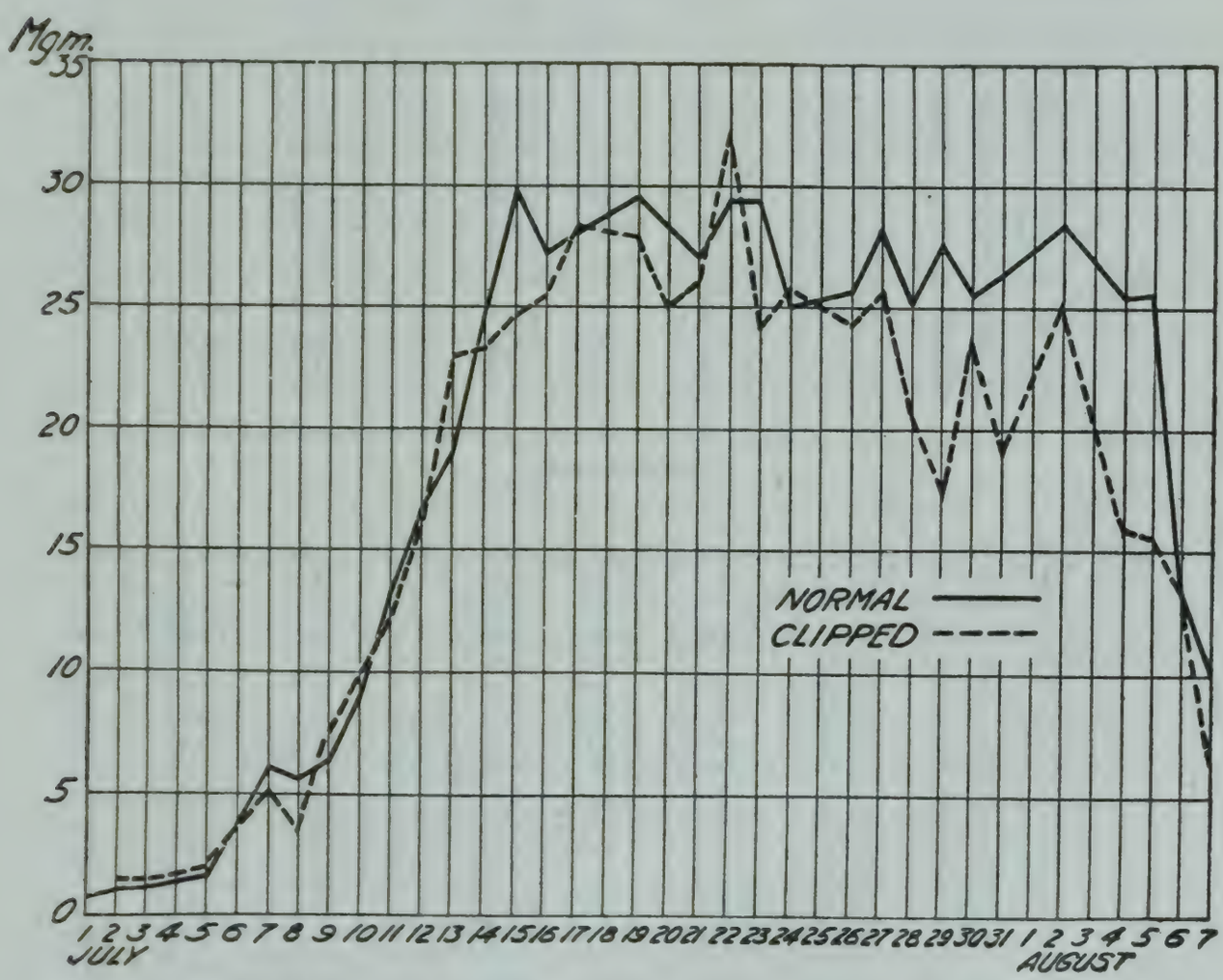

FIG. 6.—Graph showing water in kernels of Manchuria barley from normal and clipped spikes.

TABLE III.—*Average percentage and weight per kernel of dry matter, water, nitrogen, and ash in kernels from normal and clipped spikes of Manchuria barley at St. Paul, Minn., in 1915*

NORMAL SPIKES

Date.		Dry matter.	Water.	Nitrogen.	Ash.	Wet weight per kernel.	Dry Weight per kernel.	Water per kernel.	Nitrogen per kernel.	Ash per kernel.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*
July	1	22.88	77.12	5.93	17.02	1.0	0.2	0.8	0.01	0.03
	2	22.82	77.18	.....	.....	1.3	.3	1.0	.....	.....
	3	21.43	78.57	.....	7.33	1.4	.3	1.1	.....	.02
	5	21.88	78.12	.....	8.93	2.1	.5	1.6	.....	.04
	7	18.12	81.88	1.51	5.40	7.4	1.3	6.1	.02	.07
	8	19.08	80.92	1.31	5.60	6.9	1.3	5.6	.02	.07
	9	18.36	81.64	2.80	5.07	7.8	1.4	6.4	.04	.07
	10	19.27	80.73	2.70	4.37	11.9	2.3	9.6	.06	.10
	11	22.79	77.21	2.32	4.24	17.9	4.1	13.8	.10	.17
	12	24.16	75.84	2.28	3.38	22.5	5.4	17.1	.12	.18
	13	25.99	74.01	3.10	3.45	25.5	6.6	18.9	.20	.23
	14	28.58	71.42	1.54	2.94	35.0	10.0	25.0	.15	.29
	15	30.15	69.85	2.30	3.15	42.8	12.9	29.9	.30	.41
	16	33.68	66.32	2.05	3.11	41.2	13.9	27.3	.28	.43
	17	35.49	64.51	2.22	3.06	43.6	15.5	28.1	.34	.47
	19	38.87	61.13	1.92	2.90	48.4	18.8	29.6	.36	.55
	20	41.61	58.39	2.08	2.76	48.7	20.3	28.4	.42	.56
	21	40.97	59.03	1.96	2.79	46.0	18.8	27.2	.37	.52
	22	44.62	55.38	1.65	2.55	53.0	23.6	29.4	.39	.60
	23	45.73	54.27	2.15	2.48	54.2	24.8	29.4	.53	.62
	24	47.78	52.22	2.33	2.46	47.9	22.9	25.0	.53	.56
	26	49.48	50.52	2.14	2.36	50.8	25.1	25.7	.54	.59
	27	49.76	50.24	1.98	2.25	56.5	28.1	28.4	.56	.63
	28	52.23	47.77	2.16	2.46	53.1	27.7	25.4	.60	.68
	29	53.75	46.25	1.99	2.36	59.9	32.2	27.7	.64	.76
	30	52.47	47.53	2.19	2.32	53.8	28.2	25.6	.62	.65
	31	53.15	46.85	2.01	2.37	56.6	30.1	26.5	.61	.71
Aug.	2	55.89	44.11	1.91	2.24	64.4	36.0	28.4	.69	.81
	4	56.92	43.08	2.14	1.81	59.5	33.9	25.6	.73	.61
	5	59.83	40.17	1.91	1.96	63.9	38.2	25.7	.73	.75
	6	67.89	32.11	2.10	2.01	42.3	28.7	13.6	.50	.58
	7	77.90	22.10	2.16	2.27	45.6	35.5	10.1	.77	.81

CLIPPED SPIKES

July	2	21.13	78.87	9.70	11.76	1.8	0.4	1.4	0.04	0.05
	3	22.82	77.18	.....	12.22	1.7	.4	1.3	.....	.05
	5	19.91	80.09	9.16	8.46	2.4	.5	1.9	.05	.04
	7	16.68	83.32	3.61	7.09	6.4	1.1	5.3	.04	.08
	8	17.40	82.60	.....	6.53	4.5	.8	3.7	.....	.05
	9	17.51	82.49	2.68	5.55	9.2	1.6	7.6	.04	.09
	10	19.11	80.89	2.79	4.30	12.2	2.3	9.9	.06	.10
	11	21.04	78.96	3.02	4.44	15.6	3.3	12.3	.10	.15
	12	24.89	75.11	2.57	3.80	21.8	5.4	16.4	.14	.21
	13	27.48	72.52	1.77	3.44	31.8	8.7	23.1	.15	.30
	14	28.41	71.59	1.69	3.48	32.7	9.3	23.4	.16	.32
	15	30.48	69.52	2.46	3.12	35.5	10.8	24.7	.27	.34
	16	33.61	66.39	2.23	3.19	38.2	12.8	25.4	.29	.41
	17	36.26	63.74	2.14	2.98	44.5	16.1	28.4	.34	.48
	19	35.64	64.36	2.05	2.89	43.3	15.4	27.9	.32	.45
	20	41.10	58.90	1.90	3.01	42.6	17.5	25.1	.33	.53
	21	42.30	57.70	1.95	2.83	45.0	19.0	26.0	.37	.54
	22	44.93	55.07	2.16	2.50	57.5	25.8	31.7	.56	.65
	23	44.77	55.23	2.33	2.62	44.1	19.7	24.4	.46	.52
	24	46.94	53.06	2.04	2.70	48.2	22.6	25.6	.46	.61

TABLE III.—*Average percentage and weight per kernel of dry matter, water, nitrogen, and ash in kernels from normal and clipped spikes of Manchuria barley at St. Paul, Minn., in 1915*—Continued

CLIPPED SPIKES

Date.	Dry matter.	Water.	Nitrogen.	Ash.	Wet weight per kernel.	Dry Weight per kernel.	Water per kernel.	Nitrogen per kernel.	Ash per kernel.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*
July 26	48.61	51.39	2.04	2.60	47.2	22.9	24.3	0.47	0.60
27	51.70	48.30	1.88	2.48	52.9	27.3	25.6	.51	.68
28	52.60	47.40	2.27	2.76	43.6	22.9	20.7	.52	.63
29	58.56	41.44	2.17	2.48	42.6	24.9	17.7	.54	.62
30	54.39	45.61	2.51	2.38	52.2	28.4	23.8	.71	.68
31	56.49	43.51	2.46	2.59	44.2	25.0	19.2	.62	.65
Aug. 2	58.30	41.70	2.17	2.07	60.6	35.3	25.3	.77	.73
4	52.44	47.56	2.51	2.64	33.9	17.8	16.1	.45	.47
5	64.99	35.01	2.11	2.02	45.1	29.3	15.8	.62	.59
6	66.90	33.10	2.36	1.90	41.6	27.8	13.8	.66	.53
7	81.18	18.82	2.15	2.12	33.6	27.3	6.3	.59	.58

The deposition of ash, on the other hand, is maintained in the kernels of clipped spikes for a much longer period. It is only in the final days of maturation that the total ash per kernel of the normal spikes exceeds that of the kernels of the clipped spikes. In Table III it will be seen that in percentage of ash the case is reversed. The kernels of the clipped spike have an appreciably higher percentage of ash. That the total is higher in the kernels of normal spikes is due to the greater weight of those kernels. In the experiment with Hannchen barley at Aberdeen several other determinations of ash were made, and a discussion of the significance of the ash content is better made after the results from that variety have been presented.

The nitrogen content per kernel is shown graphically in figure 5. During more than half the period of growth there is little difference in the rate of the deposit of nitrogenous materials in the spikes. From July 23 to July 29 there is apparently a more active deposit in the normal spikes. The graphs become confused as the kernels ripen. As a whole, there is not much difference between the two. As there is a definite difference in the dry weight, the deposit of carbohydrates must be decidedly greater in the normal spikes during the last half of the growing period.

The water per kernel is a good index of development. In normal development the water rapidly increases after fertilization and quickly attains its maximum. It then remains stabilized, or nearly so, as long as growth is efficiently maintained. When growth is checked or maturation begins, the water content drops slowly until complete ripeness occurs. After complete ripeness it drops still more rapidly for two or three days. It will be seen in figure 6 that the water content of the kernels from clipped spikes is about equal to that of the kernels from normal spikes

until July 25. After that date the kernels from clipped spikes exhibit a rapid loss of water which becomes accelerated about August 2.

In general, the differences in the development of the kernels from normal and clipped spikes are largely evident in the tables and figures. Certain observations and deductions seem justified. The discussion of the significance of the results at Minnesota, however, has been placed with that of results at Aberdeen, Idaho.

TABLE IV.—*Growth of kernels of Hannchen barley in awned and clipped spikes at Aberdeen, Idaho, in 1916*

JULY 8

Normal spikes.								Clipped spikes.							
Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.		Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.	
A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B	A.	B.
Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0007	0.0007	2.4	1.9	.....	0.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0011	.0010	2.2	1.8	0.8	.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0012	.0012	2.3	2.3	.6	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0012	.0013	2.3	2.0	.7	.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0013	.0017	2.4	2.2	.9	1.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0014	.0017	2.1	2.4	.8	1.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0014	.0017	2.3	2.2	.8	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0014	.0017	2.5	2.1	.8	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0017	.0017	2.3	2.4	.9	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0017	.0017	2.3	2.0	1.1	1.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0013	.0017	2.4	2.5	.9	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0011	.0014	2.2	2.3	.8	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0011	.0012	2.4	2.4	.6	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0011	.0009	2.2	2.1	.7	.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.0008	.0008	1.9	1.8	.6	.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

JULY 10

0.0009	0.0019	2.1	2.6	0.7	1.2	0.5	0.7	0.0015	0.0015	2.2	2.4	0.9	0.7	0.7	0.7
.0025	.0030	2.5	2.4	1.2	1.3	.9	1.0	.0026	.0027	2.7	2.9	1.2	1.2	.8	.7
.0031	.0039	2.7	3.4	1.4	1.5	1.0	1.0	.0033	.0032	2.6	2.7	1.4	1.2	1.0	.8
.0039	.0045	3.1	3.5	1.5	1.6	1.0	1.0	.0035	.0035	2.8	3.3	1.4	1.4	1.0	.8
.0041	.0047	3.3	3.5	1.4	1.5	1.0	1.0	.0037	.0038	3.2	3.2	1.3	1.4	1.0	.9
.0048	.0047	3.7	3.7	1.4	1.4	1.0	1.1	.0043	.0043	3.4	3.5	1.5	1.3	.9	.9
.0049	.0051	3.7	4.0	1.6	1.5	1.1	1.0	.0047	.0042	3.4	3.4	1.5	1.4	1.0	1.0
.0059	.0053	4.3	4.5	1.5	1.4	1.0	1.0	.0052	.0047	3.7	3.7	1.4	1.4	1.0	.9
.0058	.0054	4.2	4.2	1.5	1.5	1.1	1.0	.0049	.0044	3.5	3.5	1.4	1.5	1.0	.9
.0052	.0054	3.9	4.2	1.4	1.5	1.0	1.0	.0048	.0044	4.2	3.7	1.4	1.4	.8	.9
.0048	.0047	4.0	3.8	1.5	1.4	1.0	.9	.0045	.0041	3.7	3.4	1.3	1.4	1.0	1.0
.0045	.0039	4.1	3.9	1.4	1.5	1.0	.8	.0036	.0035	3.0	2.8	1.2	1.3	1.0	.7
.0034	.0037	3.3	3.6	1.4	1.3	.9	1.0	.0032	.0032	3.1	3.1	1.4	1.4	.9	.9
.0019	.0025	2.3	2.8	1.1	1.3	.8	.8	.0017	.0025	2.2	2.8	1.0	1.2	.6	.9
.....	.0017	.....	1.8	.....	1.0	.....	.7	.....	.0021	.....	2.8	.....	1.1	.....	.7
.....	.....	.....	.....	.....	.....	.....	.....	.....	.0015	.....	1.9	.....	1.1	.....	.6

JULY 11

0.0026	0.0045	2.6	3.8	1.4	1.5	0.8	0.9	0.0038	0.0014	3.4	1.8	1.4	0.8	0.9	0.6
.0048	.0068	4.1	4.8	1.4	1.7	1.0	1.0	.0051	.0042	4.2	3.7	1.4	1.6	1.0	.9
.0062	.0074	4.6	5.2	1.5	1.5	1.0	.9	.0060	.0055	4.6	4.1	1.6	1.6	1.0	.9
.0069	.0081	5.1	5.7	1.6	1.6	1.2	1.0	.0073	.0063	5.3	4.9	1.5	1.5	.8	1.0
.0073	.0084	5.4	5.8	1.5	1.7	1.1	1.0	.0077	.0076	5.6	5.5	1.7	1.6	1.0	1.0
.0075	.0086	5.4	5.7	1.7	1.6	1.1	1.0	.0078	.0081	5.5	5.4	1.8	1.6	1.0	1.0
.0081	.0094	5.8	6.5	1.7	1.7	1.0	1.0	.0081	.0080	6.3	5.6	1.6	1.6	1.0	1.0
.0084	.0094	5.8	6.4	1.6	1.7	1.1	1.1	.0084	.0082	6.1	6.1	1.7	1.6	1.0	1.0
.0079	.0089	5.8	6.4	1.7	1.7	1.0	1.0	.0083	.0082	6.1	6.2	1.6	1.6	1.0	1.0
.0074	.0087	5.8	6.4	1.6	1.7	.9	1.0	.0083	.0082	6.5	5.9	1.6	1.7	1.0	1.0
.0068	.0084	5.1	6.4	1.6	1.8	.9	1.0	.0074	.0079	5.9	5.9	1.6	1.5	1.0	.9
.0058	.0074	4.4	5.7	1.5	1.6	1.0	1.0	.0069	.0071	5.7	5.5	1.5	1.5	1.0	1.0
.0042	.0066	4.0	5.2	1.5	1.6	.9	1.0	.0054	.0057	5.0	4.5	1.4	1.4	.9	1.0
.0032	.0055	3.1	4.9	1.4	1.4	.9	1.0	.0041	.0048	4.1	4.3	1.4	1.3	.8	.9
.....	.0039	.....	3.7	.....	1.4	.....	.9	.....	.0036	.....	3.7	.....	1.3	.....	.9

TABLE IV.—*Growth of kernels of Hannchen barley in awned and clipped spikes at Aberdeen, Idaho, in 1916*—Continued

JULY 12

Normal spikes.								Clipped spikes.							
Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.		Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.	
A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0020	0.0037	2.8	3.2	1.2	1.4	0.7	1.0	0.0023	0.0042	2.6	3.4	1.2	1.5	0.8	0.8
.0044	.0065	3.7	4.6	1.4	1.5	.9	1.0	.0058	.0055	4.6	4.5	1.5	1.7	.9	1.0
.0055	.0073	4.3	4.9	1.7	1.7	1.0	1.0	.0075	.0074	5.6	5.3	1.7	1.6	.9	.9
.0074	.0086	5.2	6.0	1.6	1.7	1.0	.9	.0090	.0083	6.5	5.7	1.6	1.7	.9	1.1
.0074	.0090	5.3	5.9	1.6	1.8	1.0	1.1	.0088	.0091	6.7	6.6	1.7	1.7	.9	1.0
.0081	.0096	5.6	6.4	1.8	1.8	1.0	1.0	.0098	.0099	6.9	6.9	1.7	1.7	.9	1.0
.0085	.0098	6.0	6.5	1.8	1.8	1.0	1.0	.0096	.0098	6.9	6.9	1.8	1.7	1.0	1.0
.0092	.0098	6.3	6.5	1.7	1.7	1.0	1.0	.0097	.0102	7.3	7.1	1.7	1.8	1.0	1.1
.0092	.0099	6.5	6.7	1.8	1.7	1.0	1.0	.0100	.0100	7.3	6.9	1.7	1.8	1.0	1.1
.0092	.0098	6.6	7.0	1.8	1.7	1.0	1.1	.0090	.0104	7.0	7.4	1.8	1.7	1.0	1.1
.0087	.0097	6.9	6.6	1.7	1.8	1.0	1.0	.0089	.0097	6.9	7.1	1.7	1.5	1.0	1.1
.0085	.0085	6.3	6.3	1.8	1.7	1.0	1.0	.0080	.0082	6.4	6.1	1.6	1.6	1.0	1.0
.0077	.0028	6.2	S.	1.7	.....	1.0	.....	.0069	.0073	5.8	5.5	1.6	1.6	.8	.9
.0068	.0062	5.7	5.3	1.6	1.4	1.0	1.0	.0052	.0062	4.9	5.5	1.4	1.5	.1	.8
.0050	.0044	4.3	4.2	1.5	1.4	1.0	.9	.....	.0050	.....	4.7	.....	1.5	.....	.8

JULY 13

0.0102	0.0071	6.8	5.4	1.9	1.7	1.1	1.0	0.0037	0.0064	4.8	5.3	1.6	1.5	0.7	0.9
.0130	.0114	8.2	7.5	1.9	1.8	1.2	1.1	.0103	.0094	7.2	6.6	1.8	1.7	1.0	1.0
.0146	.0121	8.6	7.5	1.9	1.8	1.2	1.1	.0140	.0116	8.3	7.5	1.9	1.7	1.3	1.2
.0153	.0145	9.2	8.5	2.0	1.9	1.4	1.2	.0155	.0125	8.8	8.3	2.0	1.7	1.4	1.1
.0160	.0146	9.3	8.9	2.0	1.9	1.4	1.2	.0169	.0141	9.2	8.5	2.0	1.9	1.5	1.2
.0175	.0157	9.6	8.8	2.2	1.9	1.5	1.4	.0184	.0145	9.5	8.8	2.1	2.0	1.5	1.4
.0187	.0168	10.0	9.1	2.2	2.0	1.4	1.4	.0184	.0144	9.4	8.7	2.1	1.8	1.5	1.3
.0188	.0162	10.0	9.3	2.1	2.2	1.4	1.4	.0179	.0149	9.0	8.8	2.0	1.9	1.4	1.3
.0184	.0172	9.9	9.6	2.2	2.0	1.5	1.5	.0178	.0145	9.2	8.4	2.2	1.9	1.5	1.4
.0173	.0167	9.5	9.3	2.2	2.0	1.4	1.4	.0196	.0147	9.0	8.5	2.3	1.9	1.5	1.2
.0175	.0149	9.6	9.1	2.1	1.9	1.5	1.4	.0160	.0149	9.0	8.5	2.0	1.9	1.4	1.3
.0158	.0137	9.3	8.7	2.1	1.9	1.4	1.4	.0138	.0137	8.7	8.5	1.9	1.9	1.4	1.3
.0135	.0129	8.6	8.5	1.9	1.8	1.3	1.2	.0126	.0127	8.5	8.3	1.9	1.9	1.2	1.3
.0126	.0103	8.5	7.3	1.9	1.7	1.4	1.1	.0086	.0106	7.0	7.7	1.6	1.7	1.1	1.2
.0105	.0085	7.7	6.9	2.0	1.5	1.1	1.0	.....	.0082	.....	6.7	.....	1.6	.....	.8
.0076	.....	6.3	.....	1.7	.....	.9	.....	.....	.....	.....	.....	.....	.....	.....	.....

JULY 14

0.0069	0.0104	5.3	7.3	1.7	1.9	0.9	1.1	0.0094	0.0098	7.3	7.3	1.7	1.8	1.0	1.2
.0117	.0153	7.6	8.4	1.8	2.1	1.1	1.3	.0139	.0108	8.6	9.1	1.8	2.1	1.4	1.4
.0151	.0161	8.7	9.0	2.1	2.1	1.3	1.4	.0167	.0200	9.3	9.4	1.9	2.2	1.6	1.5
.0154	.0179	9.0	9.1	2.0	2.1	1.3	1.5	.0173	.0207	9.6	9.8	2.0	2.0	1.5	1.5
.0177	.0196	9.4	9.4	2.1	2.3	1.4	1.6	.0191	.0220	9.6	9.9	2.1	2.2	1.5	1.6
.0182	.0199	9.5	9.6	2.2	2.1	1.4	1.6	.0189	.0227	9.7	10.2	2.0	2.3	1.6	1.6
.0180	.0203	9.7	9.7	2.0	2.1	1.4	1.5	.0196	.0244	9.9	10.4	2.3	2.3	1.5	1.7
.0185	.0208	9.4	9.5	2.1	2.1	1.5	1.7	.0195	.0250	9.9	10.5	2.3	2.4	1.5	1.7
.0186	.0208	10.0	9.9	2.2	1.9	1.5	1.6	.0194	.0247	9.6	10.4	2.2	2.5	1.6	1.6
.0171	.0209	9.4	10.0	2.1	2.3	1.5	1.5	.0193	.0242	9.6	9.9	2.3	2.5	1.5	1.7
.0159	.0192	9.5	9.6	1.9	2.3	1.4	1.6	.0164	.0236	9.4	10.3	1.9	2.6	1.4	1.6
.0134	.0179	8.8	9.3	1.9	2.2	1.3	1.5	.0146	.0222	8.8	10.0	1.9	2.3	1.3	1.7
.0110	.0152	8.0	8.7	1.7	2.0	1.1	1.4	.0138	.0205	8.9	10.0	1.8	2.3	1.4	1.5
.0094	.0128	7.5	8.5	1.8	1.9	1.1	1.2	.0100	.0171	7.8	9.5	1.7	2.1	1.2	1.4
.....	.0090	.....	7.3	.....	1.6	.....	1.2	.....	.0145	.....	8.5	.....	2.0	.....	1.4

TABLE IV.—*Growth of kernels of Hannchen barley in awned and clipped spikes at Aberdeen, Idaho, in 1916*—Continued

JULY 15

Normal spikes.								Clipped spikes.							
Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.		Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.	
A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0082	0.0045	6.4	5.0	1.8	1.5	0.9	0.7	0.0041	0.0058	4.8	5.5	1.4	1.5	0.7	0.8
.0158	.0017	8.7	8.8	1.9	2.1	1.3	1.4	.0144	.0145	8.8	8.8	1.9	1.9	1.4	1.3
.0193	.0213	9.6	9.5	2.1	2.2	1.4	1.6	.0207	.0144	9.5	9.6	2.3	2.2	1.5	1.5
.0215	.0248	10.0	9.8	2.1	2.1	1.5	1.6	.0251	.0212	10.1	9.3	2.3	2.2	1.8	1.5
.0230	.0261	10.0	10.2	2.3	2.3	1.6	1.6	.0253	.0215	10.1	9.5	2.2	2.3	1.7	1.5
.0261	.0265	10.4	10.0	2.3	2.0	1.4	1.7	.0263	.0230	10.0	9.5	2.4	2.4	1.8	1.5
.0258	.0284	10.1	10.4	2.4	2.4	1.6	1.9	.0264	.0246	10.0	9.7	2.5	2.3	1.7	1.8
.0253	.0282	10.1	10.4	2.3	2.6	1.6	1.8	.0275	.0243	10.0	9.6	2.5	2.4	1.7	1.6
.0259	.0269	10.0	10.0	2.5	2.5	1.6	1.7	.0267	.0248	10.0	10.0	2.6	2.3	1.9	1.7
.0250	.0266	10.3	10.0	2.2	2.0	1.7	1.6	.0260	.0235	9.9	9.3	2.5	2.3	1.7	1.5
.0229	.0253	10.0	10.0	2.0	2.2	1.5	1.5	.0250	.0210	9.7	9.3	2.2	2.4	1.5	1.5
.0212	.0231	9.5	9.7	2.0	2.2	1.5	1.8	.0237	.0180	9.5	9.3	2.2	2.0	1.5	1.5
.0183	.0213	9.5	9.0	2.0	2.0	1.5	1.7	.0206	.0134	9.1	8.5	2.2	1.9	1.5	1.4
.0172	.0169	9.3	9.0	2.0	2.1	1.5	1.5	.0175	.....	9.2	.....	2.0	.....	1.5	.....
.0141	.0135	8.7	8.2	1.6	1.8	1.4	1.3	.0119	.....	7.7	.....	1.8	.....	1.3	.....

JULY 17

0.0167	0.0293	9.2	10.3	2.3	2.7	1.4	2.0	0.0223	0.0225	9.5	8.3	2.6	1.9	1.5	1.4
.0334	.0323	10.2	10.5	2.8	2.9	2.2	2.2	.0340	.0254	10.4	10.0	3.0	2.5	2.0	1.8
.0370	.0363	10.6	10.6	2.9	3.0	2.1	2.1	.0366	.0298	10.0	10.2	3.0	2.8	2.0	1.8
.0411	.0396	10.9	11.2	3.1	3.0	2.3	2.1	.0398	.0339	10.4	10.0	3.2	3.0	2.2	2.1
.0404	.0400	11.1	10.6	3.1	3.1	2.3	2.2	.0384	.0351	10.0	10.0	3.2	3.0	2.2	2.0
.0436	.0413	11.0	10.2	3.3	3.0	2.2	2.1	.0388	.0368	9.8	10.5	3.2	3.2	2.0	2.1
.0436	.0423	11.2	10.3	3.2	3.3	2.3	2.2	.0385	.0362	9.7	9.2	3.2	3.2	2.1	2.1
.0442	.0406	11.1	10.5	3.2	3.2	2.3	2.2	.0393	.0344	9.8	9.4	3.2	3.0	2.2	2.2
.0447	.0413	10.6	10.2	3.4	3.2	2.3	2.2	.0385	.0349	9.7	9.8	3.2	3.0	2.2	2.0
.0422	.0392	10.5	10.3	3.3	3.0	2.4	2.0	.0384	.0315	9.8	9.5	3.4	3.0	2.3	1.9
.0405	.0392	10.6	10.0	3.3	3.1	2.3	2.0	.0339	.0299	9.7	9.1	3.0	3.0	2.1	2.0
.0387	.0375	10.4	9.8	3.3	3.0	2.2	2.1	.0316	.0277	8.9	8.9	3.1	2.9	2.0	1.9
.0365	.0343	10.0	9.5	3.1	3.0	2.2	2.2	.0298	.0245	9.0	8.6	2.8	2.7	1.9	1.9
.0314	.0320	9.7	9.8	2.8	2.9	2.0	2.1	.0255	.0166	9.1	7.9	2.5	2.5	1.6	1.6
.0260	.0287	9.5	9.0	2.6	2.8	1.8	2.0	.0201	.....	8.2	.....	2.5	.....	1.6	.....

JULY 18

0.0253	0.0279	9.3	9.3	2.7	2.9	1.6	1.8	0.0283	0.0191	10.0	8.7	2.8	2.3	1.8	1.6
.0390	.0395	10.5	10.7	3.2	3.0	2.1	2.2	.0326	.0317	10.3	10.2	2.8	2.7	1.8	1.7
.0405	.0450	10.4	10.3	3.3	3.4	2.1	2.2	.0368	.0369	10.0	10.7	3.1	3.0	2.1	2.0
.0450	.0466	10.2	10.0	3.4	3.3	2.2	2.3	.0386	.0410	10.3	10.4	3.2	3.3	2.0	2.2
.0439	.0478	11.0	10.5	3.2	3.4	2.2	2.4	.0417	.0430	10.1	10.2	3.1	3.2	2.3	2.2
.0455	.0508	10.7	10.4	3.3	3.6	2.3	2.5	.0423	.0434	10.2	10.1	3.0	3.3	2.2	2.2
.0465	.0504	10.1	10.7	3.5	3.5	2.2	2.6	.0418	.0427	10.0	9.3	3.2	3.3	2.2	2.2
.0458	.0500	10.5	10.8	3.4	3.6	2.3	2.4	.0408	.0441	9.6	10.2	3.3	3.2	2.2	2.2
.0439	.0431	9.5	10.2	3.4	3.6	2.0	2.4	.0388	.0454	9.8	10.2	3.2	3.3	2.2	2.5
.0430	.0468	9.7	10.1	3.4	3.4	2.1	2.4	.0390	.0415	9.7	9.7	3.2	3.3	2.3	2.4
.0419	.0431	10.1	9.5	3.3	3.5	2.3	2.4	.0334	.0402	9.2	10.1	3.2	3.2	2.0	2.1
.0383	.0416	9.7	9.1	3.3	3.4	2.3	2.4	.0305	.0387	9.2	9.6	3.0	3.1	2.0	2.3
.0324	.0388	9.3	9.3	2.8	3.3	1.9	2.2	.0271	.0353	8.7	9.7	2.8	3.2	1.7	2.2
.0311	.0350	8.6	9.2	2.9	3.1	2.0	2.2	.0197	.0330	7.8	9.2	2.5	3.0	1.5	2.1
.....	.....	.....	.....	.....	.....	.....	.....	.....	.0279	.....	8.4	.....	2.8	.....	1.9

TABLE IV.—*Growth of kernels of Hannchen barley in awned and clipped spikes at Aberdeen, Idaho, in 1916*—Continued

JULY 19

Normal spikes.								Clipped spikes.							
Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.		Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.	
A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0205	0.0337	9.2	9.7	2.5	3.1	1.7	2.1	0.0137	0.0253	7.5	9.5	2.2	2.9	1.5	1.7
.0391	.0427	10.1	10.6	3.2	3.3	2.1	2.2	.0324	.0374	9.8	9.5	2.8	3.2	2.0	2.0
.0396	.0475	10.4	10.5	3.3	3.4	2.1	2.5	.0380	.0409	10.1	10.2	3.2	3.3	2.2	2.3
.0445	.0511	9.9	10.8	3.3	3.5	2.3	2.3	.0408	.0422	10.1	10.4	3.4	3.3	2.3	2.1
.0457	.0481	10.4	10.7	3.4	3.7	2.3	2.5	.0397	.0441	10.1	10.2	3.4	3.4	2.3	2.3
.0473	.0489	10.3	10.5	3.4	3.5	2.3	2.3	.0429	.0425	10.4	10.4	3.3	3.3	2.4	2.1
.0465	.0486	10.3	10.4	3.4	3.6	2.5	2.5	.0431	.0435	9.6	9.7	3.3	3.4	2.4	2.2
.0462	.0488	9.6	10.8	3.5	3.5	2.5	2.4	.0409	.0443	9.6	9.7	3.2	3.4	2.4	2.3
.0467	.0483	10.2	10.0	3.4	3.5	2.4	2.5	.0382	.0434	9.7	9.6	3.3	3.4	2.2	2.4
.0405	.0459	10.2	10.0	3.4	3.4	2.2	2.2	.0391	.0402	9.6	9.9	3.4	3.3	2.4	2.2
.0448	.0457	9.7	9.7	3.5	3.4	2.3	2.5	.0373	.0388	9.2	9.6	3.4	3.4	2.1	2.2
.0400	.0438	9.6	10.1	3.2	3.4	2.4	2.3	.0343	.0363	8.7	9.6	3.2	3.3	2.1	2.1
.0381	.0375	9.6	9.2	3.2	3.3	2.3	2.3	.0311	.0328	8.9	8.6	3.0	3.2	2.1	2.2
.0356	.0345	9.2	9.6	3.3	3.2	2.3	2.1	.0226	.0264	8.2	8.7	2.8	3.0	1.8	1.9
.0278	.....	9.0	.....	3.0	.....	2.2	.....	.....	.0198	.....	8.0	.....	2.6	.....	1.6

JULY 20

0.0117	0.0356	7.6	10.7	2.1	3.1	1.3	2.2	0.0395	0.0359	10.8	9.8	3.2	3.1	2.0	2.3
.0419	.0421	10.3	11.0	3.3	3.4	2.3	2.3	.0435	.0407	10.4	10.2	3.3	3.3	2.3	2.3
.0477	.0422	10.3	10.2	3.6	3.2	2.5	2.2	.0315	.0437	9.9	10.5	3.0	3.2	1.6	2.4
.0492	.0447	10.6	11.0	3.6	3.3	2.5	2.3	.0510	.0442	10.8	10.8	3.5	3.1	2.5	2.3
.0521	.0467	10.7	11.0	3.8	3.2	2.4	2.3	.0478	.0460	10.4	10.4	3.5	3.4	2.1	2.4
.0500	.0455	10.8	10.9	3.6	3.3	2.4	2.3	.0491	.0456	10.5	10.4	3.5	3.3	2.5	2.1
.0505	.0440	10.7	10.6	3.7	3.2	2.4	2.2	.0433	.0450	10.4	10.1	3.4	3.3	2.3	2.5
.0514	.0458	10.4	10.3	3.6	3.3	2.5	2.5	.0470	.0430	10.2	10.1	3.5	3.3	2.2	2.2
.0492	.0444	10.0	10.5	3.5	3.3	2.5	2.3	.0442	.0400	10.2	9.3	3.5	3.0	2.4	2.1
.0495	.0443	10.4	10.0	3.6	3.3	2.5	2.3	.0410	.0403	10.2	9.8	3.4	3.0	2.2	2.0
.0475	.0419	10.0	10.4	3.5	3.3	2.4	2.3	.0392	.0384	9.9	9.7	3.2	2.9	2.3	2.1
.0455	.0409	10.0	9.7	3.4	3.2	2.4	2.2	.0365	.0332	9.8	9.7	3.2	3.1	2.2	2.1
.0411	.0363	9.7	9.7	3.5	3.2	2.3	2.0	.0320	.0293	9.3	8.9	3.2	2.9	2.0	2.0
.0382	.0331	9.6	9.8	3.3	2.8	2.3	2.0	.0247	.0199	9.0	8.5	2.9	2.7	1.8	1.7
.0326	.0280	9.3	9.1	2.8	2.8	2.0	2.0	.....	.....	.....	.....	.....	.....	.....	.....

July 21

0.0200	0.0228	8.9	9.3	2.4	2.6	1.7	1.8	0.0257	0.0355	9.4	9.8	2.8	3.2	1.9	1.9
.0446	.0420	10.6	10.3	3.4	3.2	2.2	2.2	.0427	.0433	10.0	10.2	3.5	3.5	2.4	2.3
.0522	.0492	10.7	11.0	3.5	3.5	2.3	2.3	.0462	.0411	10.6	10.4	3.4	3.5	2.3	2.2
.0538	.0505	10.8	11.0	3.7	3.6	2.4	2.2	.0465	.0488	10.2	10.5	3.3	3.5	2.2	2.3
.0596	.0527	10.6	10.6	3.9	3.6	2.4	2.5	.0508	.0489	10.3	10.8	3.5	3.7	2.5	2.3
.0487	.0505	10.7	10.6	3.7	3.4	2.4	2.5	.0492	.0473	9.4	10.1	3.7	3.5	2.4	2.3
.0542	.0517	10.7	11.0	3.8	3.6	2.5	2.5	.0477	.0463	10.0	9.8	3.5	3.5	2.4	2.3
.0555	.0517	10.7	10.6	3.8	3.4	2.6	2.4	.0456	.0461	10.3	10.3	3.5	3.5	2.3	2.3
.0555	.0514	10.8	10.3	3.8	3.7	2.5	2.5	.0454	.0455	10.0	9.7	3.5	3.4	2.3	2.2
.0509	.0490	10.4	10.3	3.8	3.5	2.5	2.4	.0439	.0429	9.5	9.9	3.5	3.5	2.3	2.4
.0489	.0481	10.3	10.5	3.7	3.5	2.6	2.4	.0416	.0416	10.0	9.8	3.5	3.1	2.1	2.2
.0475	.0442	10.1	10.3	3.7	3.5	2.5	2.4	.0387	.0419	9.0	9.5	3.1	3.3	2.1	2.3
.0434	.0412	10.1	9.6	3.6	3.4	2.4	2.3	.0359	.0356	9.6	9.3	3.2	3.3	2.3	2.1
.0412	.0373	10.0	9.7	3.4	3.3	2.2	2.2	.0333	.0350	9.1	9.0	3.2	3.2	2.2	2.0
.0339	.0289	9.5	9.1	3.2	3.1	2.3	2.0	.0212	.....	8.4	.....	2.7	.....	1.9	.....

TABLE IV.—*Growth of kernels of Hannchen barley in awned and clipped spikes at Aberdeen, Idaho, in 1916*—Continued

July 22

Normal spikes.								Clipped spikes.							
Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.		Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.	
A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0300	0.0164	9.6	8.0	2.8	2.5	1.8	1.8	0.0203	0.0238	8.2	9.0	2.5	2.5	1.5	1.7
.0558	.0433	10.8	10.5	3.8	3.5	2.6	2.6	.0437	.0382	10.0	10.0	3.5	3.2	2.0	1.9
.0580	.0493	10.9	10.4	3.8	3.5	2.6	2.6	.0544	.0464	10.2	9.8	3.7	3.4	2.3	2.1
.0593	.0526	10.8	10.7	3.6	3.6	2.4	2.4	.0575	.0473	10.4	10.1	3.6	3.5	2.3	2.1
.0600	.0494	10.8	9.8	4.0	3.4	2.6	2.6	.0575	.0524	10.8	10.5	3.7	3.5	2.5	2.5
.0570	.0519	10.5	10.7	3.7	3.6	2.3	2.3	.0550	.0503	10.4	9.5	3.8	3.5	2.5	2.3
.0595	.0539	10.5	10.0	3.9	3.5	2.6	2.6	.0563	.0546	10.0	10.0	3.9	3.7	2.5	2.4
.0599	.0493	10.7	10.0	3.8	3.6	2.7	2.7	.0557	.0523	10.0	10.4	3.6	3.6	2.5	2.5
.0605	.0516	10.5	9.7	3.9	3.5	2.7	2.7	.0557	.0514	9.5	9.7	3.6	3.7	2.5	2.5
.0582	.0504	10.5	10.5	3.9	3.6	2.8	2.8	.0495	.0503	9.9	10.0	3.6	3.5	2.3	2.5
.0566	.0487	10.5	10.1	3.8	3.5	2.6	2.6	.0478	.0483	9.5	10.2	3.5	3.5	2.3	2.5
.0538	.0486	10.0	10.0	3.5	3.5	2.4	2.4	.0460	.0462	10.0	9.6	3.4	3.5	2.1	2.3
.0505	.0464	10.0	9.8	3.6	3.6	2.4	2.4	.0432	.0428	9.0	9.4	3.7	3.5	2.3	2.2
.0479	.0413	9.2	9.5	3.6	3.2	2.5	2.5	.0388	.0405	9.3	9.1	3.0	3.4	2.1	2.2
.0419	.0385	9.0	9.0	3.5	3.1	2.4	2.4	.0281	.0325	9.7	8.3	2.8	3.1	1.9	2.0

JULY 24

0.0491	0.0513	10.3	10.2	3.7	3.6	2.4	2.5	0.0294	0.0489	9.3	9.6	3.0	3.6	1.7	2.4
.0591	.0577	10.5	10.7	3.7	3.6	2.6	2.5	.0524	.0561	10.5	10.6	3.7	3.7	2.3	2.5
.0596	.0606	10.5	10.7	3.9	3.8	2.7	2.7	.0576	.0534	10.5	10.5	3.9	3.7	2.4	2.3
.0633	.0593	10.5	10.8	3.9	3.8	2.9	2.5	.0588	.0595	10.6	10.7	3.9	3.8	2.5	2.5
.0607	.0629	10.5	10.8	3.9	3.9	2.5	2.7	.0632	.0587	10.7	10.5	4.0	3.7	2.6	2.4
.0645	.0658	10.5	10.8	4.2	4.0	2.6	2.8	.0585	.0562	10.5	10.3	3.9	3.7	2.6	2.6
.0625	.0659	10.7	10.4	3.8	4.0	2.7	2.8	.0602	.0612	10.3	10.1	3.9	3.8	2.7	2.7
.0580	.0690	10.3	10.8	3.9	4.1	2.6	2.9	.0555	.0575	10.4	10.0	3.7	3.7	2.5	2.8
.0605	.0648	10.5	10.6	3.8	4.0	2.6	2.7	.0515	.0557	10.0	9.9	3.5	3.7	2.5	2.5
.0608	.0634	10.5	10.4	3.8	3.8	2.7	2.8	.0544	.0544	10.2	9.6	3.6	3.7	2.5	2.6
.0531	.0532	10.2	10.4	3.8	3.7	2.5	2.7	.0528	.0508	9.8	9.1	3.6	3.6	2.4	2.5
.0534	.0559	10.2	10.2	3.7	3.7	2.5	2.5	.0490	.0440	9.5	9.7	3.6	3.5	2.3	2.4
.0470	.0554	9.5	9.6	3.5	3.7	2.4	2.6	.0453	.0453	9.6	8.8	3.4	3.4	2.4	2.5
.0454	.0527	9.1	10.0	3.4	3.6	2.5	2.7	.0373	.....	9.1	.....	3.1	.....	2.1	.....
.....	.0450	.....	9.3	.....	3.4	.....	2.5	.....	.....	.....	.....	.....	.....	.....	.....
.....	.0388	.....	8.7	.....	3.3	.....	2.3	.....	.....	.....	.....	.....	.....	.....	.....

JULY 25

0.0300	0.0552	8.7	10.4	2.9	3.7	1.9	2.4	0.0480	0.0235	10.0	8.5	3.6	2.6	2.4	1.5
.0583	.0624	10.4	10.9	3.7	3.9	2.5	2.7	.0600	.0465	10.8	9.5	3.7	3.6	2.5	2.3
.0605	.0603	10.9	10.5	3.8	3.7	2.6	2.6	.0624	.0485	11.0	10.0	3.8	3.5	2.7	2.5
.0650	.0633	11.0	10.7	3.9	4.0	2.7	2.6	.0604	.0517	10.7	9.4	3.6	3.7	2.6	2.3
.0608	.0636	10.3	11.0	3.8	3.9	2.7	2.6	.0660	.0531	10.6	10.5	4.0	3.6	2.7	2.4
.0650	.0619	10.8	10.5	3.8	3.7	2.7	2.5	.0653	.0528	11.0	9.5	3.9	3.7	2.7	2.3
.0639	.0613	10.6	10.8	3.7	3.8	2.8	2.7	.0635	.0502	11.0	10.2	3.6	3.7	2.5	2.4
.0628	.0587	10.6	10.3	3.8	3.7	2.6	2.6	.0634	.0515	10.8	10.2	3.7	3.4	2.3	2.4
.0629	.0608	10.4	10.6	3.8	3.8	2.8	2.7	.0638	.0515	10.0	9.9	3.6	3.4	2.8	2.4
.0615	.0590	10.4	10.3	4.0	3.8	2.5	2.7	.0593	.0500	10.3	10.0	3.9	3.7	2.6	2.4
.0577	.0573	10.2	10.3	3.6	3.8	2.7	2.7	.0585	.0483	10.5	9.6	3.5	3.6	2.5	2.5
.0568	.0569	10.1	9.7	3.8	3.5	2.6	2.6	.0578	.0482	10.2	9.5	3.7	3.4	2.7	2.4
.0548	.0556	9.7	9.6	3.7	3.7	2.6	2.5	.0569	.0430	10.0	9.3	3.6	3.0	2.6	2.2
.0526	.0500	9.7	9.5	3.4	3.5	2.8	2.6	.0483	.0418	9.7	9.3	3.5	3.0	2.5	2.3
.0475	.0461	9.0	9.2	3.6	3.1	2.5	2.4	.0400	.0335	9.0	8.6	3.1	3.1	2.1	2.0
.0392	.0364	9.0	9.0	3.3	3.3	2.3	2.1	.....	.....	.....	.....	.....	.....	.....	.....

TABLE IV.—*Growth of kernels of Hannchen barley in awned and clipped spikes at Aberdeen, Idaho, in 1916*—Continued

JULY 26

Normal spikes.								Clipped spikes.							
Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.		Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.	
A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0304	0.0382	9.2	9.2	3.0	3.3	1.8	2.0	0.0394	0.0368	9.0	9.0	3.3	3.0	2.0	1.8
.0569	.0588	9.7	10.8	3.5	3.8	2.6	2.5	.0542	.0614	10.8	10.0	3.7	3.5	2.3	2.5
.0619	.0640	9.7	10.8	3.9	3.5	2.4	2.5	.0614	.0642	10.5	10.5	3.7	3.5	2.7	2.7
.0660	.0700	10.7	10.8	3.8	3.9	2.7	2.6	.0670	.0669	10.7	10.8	3.8	3.7	2.5	2.7
.0708	.0659	10.7	10.5	4.0	4.0	2.8	2.6	.0655	.0652	10.6	10.5	3.7	3.7	2.6	2.5
.0669	.0672	10.7	10.9	3.8	4.0	2.8	2.8	.0658	.0624	10.5	10.5	3.7	3.8	2.8	2.5
.0650	.0673	10.2	10.7	3.7	3.9	2.6	2.8	.0651	.0657	10.7	10.5	3.7	3.7	2.8	2.8
.0696	.0671	10.8	11.0	3.9	3.9	2.7	2.6	.0665	.0643	10.5	10.2	3.9	3.9	2.8	2.7
.0681	.0645	10.2	10.3	3.8	3.8	2.6	2.6	.0650	.0600	10.3	10.0	3.8	3.7	2.6	2.5
.0654	.0634	10.4	10.3	3.7	3.6	2.6	2.5	.0653	.0600	10.3	10.0	3.7	3.8	2.7	2.6
.0640	.0626	10.4	10.4	3.8	3.8	2.7	2.6	.0602	.0568	10.0	10.0	3.8	3.4	2.7	2.5
.0607	.0557	10.0	9.7	3.9	3.7	2.5	2.5	.0588	.0530	10.0	9.5	3.6	3.5	2.7	2.5
.0607	.0540	10.0	9.6	3.7	3.6	2.5	2.6	.0505	.0486	9.5	9.2	3.2	3.5	2.5	2.5
.0546	.0485	9.5	8.9	3.5	3.5	2.5	2.6	.0456	.0353	9.0	8.7	3.5	3.2	2.3	1.9
.0502	.....	9.5	.....	3.5	.....	2.5	.....	.0332	.....	8.0	.....	3.3	.....	2.0	.....

JULY 27

0.0541	0.0427	10.0	9.3	3.5	3.0	2.5	2.1	0.0275	0.0357	8.5	9.5	2.5	3.0	2.0	2.0
.0558	.0614	10.3	10.2	3.7	3.2	2.5	2.4	.0458	.0618	9.8	10.0	3.5	3.9	2.2	2.6
.0604	.0653	10.5	10.5	3.5	3.6	2.5	2.5	.0538	.0662	10.0	10.5	3.5	3.6	2.5	2.8
.0620	.0685	10.5	10.5	3.8	3.8	2.6	2.7	.0581	.0622	10.1	10.0	3.7	3.8	2.3	2.7
.0609	.0655	10.0	10.5	3.8	3.8	2.5	2.4	.0583	.0656	10.2	10.3	3.5	3.8	2.5	2.8
.0592	.0664	10.0	10.2	3.6	3.8	2.5	2.6	.0552	.0637	10.2	10.3	3.2	3.9	2.5	2.7
.0583	.0656	9.6	10.4	3.6	3.8	2.6	2.7	.0567	.0656	9.4	9.6	3.4	3.7	2.4	2.6
.0600	.0622	9.6	10.0	3.6	3.7	2.5	2.6	.0579	.0615	9.8	10.2	3.6	3.7	2.7	2.7
.0554	.0629	9.3	10.0	3.5	3.5	2.5	2.5	.0538	.0619	9.8	9.8	3.4	3.7	2.6	2.6
.0562	.0627	9.6	9.5	3.7	3.9	2.6	2.6	.0516	.0579	9.8	10.0	3.4	3.6	2.3	2.7
.0530	.0603	9.2	9.0	3.5	3.6	2.5	2.7	.0487	.0564	9.0	9.2	3.5	3.4	2.5	2.3
.0488	.0589	9.2	9.5	3.4	3.7	2.3	2.7	.0486	.0518	9.6	9.0	3.5	3.3	2.6	2.4
.0457	.0545	9.0	9.2	3.2	3.5	2.3	2.4	.0416	.0471	9.0	9.5	3.3	3.5	2.2	2.4
.....	.0475	.....	8.8	.....	3.3	.....	2.4	.0224	.0343	8.3	9.2	2.7	3.2	1.8	2.1

JULY 28

0.0345	0.0190	8.5	7.2	3.2	2.5	1.8	1.6	0.0362	0.0233	9.1	7.7	3.4	2.7	2.1	1.8
.0589	.0574	10.5	10.0	3.6	3.5	2.5	2.7	.0530	.0552	9.8	10.0	3.7	3.4	2.3	2.8
.0640	.0637	10.8	10.0	4.0	3.8	2.6	2.7	.0602	.0619	10.0	10.5	3.8	3.8	2.7	2.5
.0652	.0651	11.0	10.6	3.8	3.8	2.6	2.8	.0614	.0603	10.0	10.5	3.7	3.7	2.5	2.6
.0688	.0671	10.7	10.0	4.0	4.0	2.7	2.8	.0642	.0632	10.7	10.5	3.8	3.7	2.7	2.5
.0667	.0658	10.6	11.0	3.8	3.8	2.8	2.7	.0625	.0638	10.0	10.0	3.8	3.7	2.7	2.8
.0657	.0688	10.0	10.5	3.8	3.7	2.9	2.8	.0619	.0660	9.9	10.0	3.8	3.5	2.8	2.8
.0625	.0683	10.5	10.2	3.8	4.0	2.7	2.8	.0604	.0616	9.8	10.2	3.8	3.7	2.8	2.7
.0608	.0695	9.6	10.4	3.8	4.0	2.7	2.9	.0585	.0600	10.0	10.0	3.7	3.5	2.8	2.7
.0618	.0657	10.0	10.0	3.7	3.9	2.6	2.8	.0578	.0585	9.3	10.2	3.8	3.7	2.5	2.6
.0578	.0620	9.8	9.5	3.5	3.7	2.7	2.7	.0560	.0560	9.7	10.1	3.7	3.7	2.7	2.6
.0542	.0602	10.0	10.0	3.7	3.8	2.6	2.8	.0512	.0572	9.0	10.0	3.5	3.7	2.3	2.8
.0502	.0575	9.7	9.7	3.7	3.7	2.5	2.6	.0504	.0528	9.0	9.4	3.4	3.5	2.4	2.6
.0452	.0502	9.2	9.4	3.5	3.6	2.5	2.6	.0441	.0485	8.7	9.0	3.4	3.3	2.4	2.6
.....	.0489	.....	9.2	.....	3.6	.....	2.5	.0279	.0427	8.0	8.5	2.8	3.4	1.9	2.5

TABLE IV.—*Growth of kernels of Hannchen barley in awned and clipped spikes at Aberdeen, Idaho, in 1916*—Continued

JULY 29

Normal spikes.								Clipped spikes.							
Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.		Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.	
A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0360	0.0454	9.0	9.2	3.3	3.5	2.1	2.3	0.0523	0.0500	9.8	10.0	3.5	3.5	2.3	2.3
.0686	.0685	10.3	10.5	3.9	3.7	2.7	2.7	.0650	.0616	10.2	10.0	3.8	3.7	2.7	2.6
.0727	.0739	11.0	10.0	4.0	3.9	2.8	2.8	.0682	.0633	10.4	9.9	3.7	3.8	2.7	2.6
.0806	.0719	11.4	10.7	4.2	4.0	2.9	2.8	.0718	.0640	10.4	10.0	3.9	3.7	2.7	2.6
.0750	.0739	10.4	10.0	4.1	4.0	2.8	2.9	.0709	.0637	10.0	10.5	4.0	3.7	2.7	2.5
.0785	.0683	10.8	11.0	4.2	3.8	3.0	2.8	.0688	.0629	10.0	10.0	3.8	3.8	2.7	2.7
.0752	.0692	10.0	10.0	4.2	4.0	2.8	2.8	.0697	.0610	10.5	10.2	4.0	3.8	2.8	2.5
.0765	.0667	10.1	10.0	4.0	3.9	2.9	2.7	.0690	.0621	10.1	10.2	3.9	3.8	2.7	2.6
.0764	.0648	10.1	10.0	4.1	3.8	2.9	2.8	.0670	.0572	9.5	9.3	3.8	3.7	2.6	2.6
.0713	.0641	10.6	10.2	3.8	3.8	2.8	2.7	.0651	.0540	9.2	9.5	3.7	3.5	2.6	2.5
.0724	.0574	10.0	9.6	4.0	3.7	2.8	2.6	.0622	.0548	9.8	9.0	3.7	3.6	2.7	2.6
.0650	.0597	9.2	9.5	4.0	3.7	2.8	2.7	.0629	.0487	9.5	8.8	3.7	3.5	2.7	2.5
.0634	.0540	10.0	8.7	3.8	3.7	2.8	2.6	.0571	.0455	9.6	9.0	3.6	3.4	2.6	2.4
.0580	.0460	9.5	8.5	3.8	3.5	2.7	2.4	.0550	.0374	9.4	9.0	3.7	3.3	2.7	2.2
.0537	.....	9.7	.....	3.6	.....	2.5	.....	.0525	.....	9.0	.....	3.5	.....	2.6	.....
.....	.....	.....	.....	.....	.....	.....	.....	.0445	.....	8.6	.....	3.5	.....	2.3	.....

JULY 31

0.0218	0.0513	7.9	9.5	2.8	3.5	1.7	2.3	0.0250	0.0451	8.4	9.5	2.8	3.4	1.8	2.3
.0600	.0735	9.9	11.7	3.8	4.0	2.7	2.8	.0592	.0566	9.8	10.0	3.7	3.7	2.5	2.4
.0689	.0785	10.5	11.5	3.9	4.0	2.7	2.9	.0625	.0620	10.0	10.3	3.7	3.5	2.5	2.5
.0677	.0726	10.5	11.0	3.9	4.0	2.8	2.8	.0624	.0672	10.1	9.8	3.8	3.8	2.6	2.6
.0735	.0740	10.6	10.0	3.9	4.0	2.8	2.7	.0633	.0643	10.3	10.1	3.7	3.7	2.6	2.7
.0743	.0660	11.0	9.8	4.0	3.7	2.9	2.6	.0651	.0642	10.3	10.4	3.8	3.7	2.8	2.6
.0704	.0687	11.0	10.5	3.9	3.9	2.9	2.8	.0636	.0625	10.2	9.7	3.7	3.7	2.6	2.7
.0692	.0725	10.4	10.8	4.0	3.8	2.8	2.8	.0622	.0631	10.2	10.0	3.7	3.7	2.6	2.7
.0656	.0689	10.4	10.5	3.8	3.7	2.7	2.8	.0590	.0608	9.7	10.2	3.7	3.7	2.6	2.6
.0689	.0679	10.0	10.5	3.9	3.8	2.8	2.8	.0588	.0590	9.9	10.0	3.8	3.7	2.6	2.7
.0630	.0685	10.0	10.8	3.8	3.8	2.7	2.8	.0588	.0554	9.5	9.6	3.7	3.7	2.7	2.6
.0627	.0668	10.0	10.5	3.7	3.9	2.7	2.8	.0570	.0564	9.3	9.5	3.7	3.6	2.5	2.5
.0582	.0649	9.7	10.2	3.7	3.7	2.6	2.7	.0511	.0468	9.4	10.0	3.6	3.5	2.5	2.5
.0517	.0605	9.5	9.6	3.5	3.6	2.5	2.6	.0493	.0459	9.3	9.2	3.5	3.4	2.5	2.4
.0518	.0550	8.8	9.2	3.5	3.5	2.6	2.6	.0422	.0429	8.6	8.9	3.4	3.3	2.4	2.4
.0430	.0388	8.6	8.0	3.4	3.1	2.5	2.3	.0241	.....	8.0	.....	2.7	.....	2.0	.....

AUGUST 1

0.0447	0.0494	9.5	9.5	3.2	3.4	2.4	2.4	0.0488	0.0330	9.6	8.3	3.5	3.1	2.5	2.1
.0655	.0641	10.0	10.0	3.8	3.8	2.8	2.7	.0644	.0589	10.3	10.0	3.7	3.7	2.7	2.6
.0664	.0692	10.2	10.4	3.8	3.9	2.8	2.7	.0634	.0636	10.3	10.7	3.7	3.8	2.7	2.7
.0694	.0682	10.7	10.5	4.0	3.9	2.7	2.7	.0648	.0653	10.5	9.8	3.7	3.9	2.7	2.7
.0704	.0660	10.7	10.8	3.9	3.8	2.6	2.8	.0659	.0663	10.5	10.1	3.7	3.9	2.6	2.8
.0713	.0632	10.4	10.4	3.8	3.7	2.7	2.7	.0650	.0666	10.3	10.0	3.7	3.8	2.7	2.8
.0705	.0650	10.5	10.0	3.9	3.8	2.9	2.7	.0627	.0611	10.4	10.0	3.7	3.7	2.8	2.6
.0687	.0675	10.0	10.4	3.9	3.9	2.8	2.6	.0592	.0623	9.8	9.9	3.7	3.7	2.7	2.6
.0678	.0661	10.0	10.2	3.9	3.8	2.9	2.7	.0588	.0612	10.1	9.9	3.7	3.7	2.7	2.7
.0650	.0655	10.5	10.0	3.8	3.8	2.9	2.8	.0578	.0568	10.2	10.0	3.7	3.6	2.7	2.6
.0639	.0651	10.0	9.9	3.8	3.8	2.8	2.8	.0519	.0540	9.6	9.3	3.7	3.6	2.6	2.6
.0590	.0625	9.9	10.1	3.8	3.8	2.8	2.8	.0539	.0500	9.0	9.6	3.7	3.5	2.7	2.6
.0627	.0554	9.7	9.5	3.8	3.5	2.8	2.6	.0511	.0464	9.0	9.2	3.7	3.4	2.5	2.5
.0571	.0588	9.5	9.3	3.7	3.7	2.8	2.8	.0500	.0461	9.0	9.8	3.6	3.5	2.5	2.5
.0490	.0516	9.5	8.6	3.6	3.6	2.7	2.7	.0443	.0370	9.1	8.5	3.4	3.2	2.5	2.3
.0376	.0424	8.5	8.3	3.3	3.4	2.4	2.6	.0342	.....	9.5	.....	3.2	.....	2.4	.....

TABLE IV.—*Growth of kernels of Hannchen barley in awned and clipped spikes at Aberdeen, Idaho, in 1916*—Continued

AUGUST 2

Normal spikes.								Clipped spikes.							
Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.		Weight.		Length.		Lateral diameter.		Dorso-ventral diameter.	
A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.	B.
Gm.	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Gm.*	*Gm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
0.0561	0.0404	9.8	9.0	3.7	3.2	2.6	2.3	0.0439	0.0232	9.1	7.7	3.2	2.7	2.3	1.6
.0605	.0600	10.0	9.6	3.7	3.6	2.6	2.7	.0614	.0577	10.0	10.0	3.7	3.7	2.6	2.5
.0606	.0617	10.5	10.7	3.8	3.7	2.7	2.6	.0632	.0614	10.3	11.0	3.7	3.7	2.7	2.6
.0604	.0631	9.7	10.5	3.7	3.7	2.6	2.7	.0612	.0625	10.0	10.0	3.5	3.7	2.7	2.7
.0564	.0654	10.3	10.3	3.6	3.8	2.6	2.8	.0598	.0580	9.5	10.3	3.5	3.5	2.7	2.6
.0542	.0633	9.7	10.5	3.6	3.7	2.5	2.8	.0600	.0564	9.3	10.3	3.6	3.5	2.6	2.5
.0545	.0605	9.8	10.1	3.5	3.7	2.6	2.8	.0557	.0562	9.6	10.1	3.6	3.5	2.6	2.6
.0541	.0585	10.2	10.0	3.5	3.7	2.6	2.8	.0525	.0514	9.5	9.7	3.5	3.4	2.8	2.6
.0512	.0484	9.5	10.0	3.5	3.2	2.7	2.5	.0482	.0459	8.8	9.2	3.4	3.4	2.7	2.5
.0430	.0518	9.5	9.4	3.3	3.4	2.5	2.7	.0460	.0420	9.1	9.5	3.4	3.3	2.7	2.5
.0500	.0485	9.2	9.0	3.4	3.4	2.6	2.7	.0418	.0440	8.7	9.0	3.4	3.4	2.6	2.5
.0403	.0455	8.8	8.9	3.2	3.4	2.4	2.6	.0380	.0363	8.2	9.2	3.2	3.1	2.5	2.1
.0310	.0373	8.5	8.6	2.9	3.2	2.5	2.5	.0334	.0339	8.0	8.5	3.2	3.1	2.5	2.3
.....	.0250	.....	7.5	.....	2.5	.....	2.0	.0218	.....	7.0	.....	2.7	.....	2.3	.....

AUGUST 3

0.0275	0.0484	7.6	9.4	2.8	3.4	1.9	2.4	0.0360	0.0418	8.7	8.6	3.2	3.2	2.1	2.3
.0636	.0639	10.0	10.3	3.7	3.7	2.7	2.7	.0561	.0511	10.0	9.6	3.6	3.6	2.5	2.5
.0634	.0650	10.1	10.0	3.7	3.7	2.7	2.7	.0550	.0532	10.1	10.1	3.5	3.4	2.6	2.5
.0648	.0644	10.1	10.7	3.7	3.6	2.8	2.6	.0580	.0542	10.4	10.1	3.5	3.5	2.6	2.6
.0627	.0650	10.0	10.5	3.7	3.5	2.7	2.7	.0559	.0534	9.8	9.8	3.5	3.4	2.7	2.6
.0606	.0645	9.8	10.6	3.6	3.7	2.7	2.7	.0508	.0440	9.1	9.8	3.4	3.2	2.7	2.5
.0583	.0645	9.4	10.3	3.5	3.7	2.6	2.7	.0476	.0460	9.9	9.7	3.4	3.3	2.6	2.6
.0508	.0614	9.5	10.0	3.6	3.6	2.6	2.7	.0485	.0445	9.7	9.2	3.4	3.3	2.6	2.5
.0508	.0540	9.5	10.1	3.4	3.5	2.6	2.6	.0434	.0425	9.3	9.0	3.3	3.2	2.6	2.5
.0433	.0527	9.0	10.7	3.3	3.4	2.6	2.6	.0419	.0407	9.0	9.5	3.3	3.2	2.6	2.5
.0418	.0505	8.8	9.8	3.2	3.5	2.5	2.6	.0400	.0385	9.3	8.2	3.2	3.2	2.5	2.5
.0428	.0482	9.2	9.4	3.4	3.5	2.6	2.6	.0374	.0362	8.4	8.4	3.2	3.2	2.5	2.3
.0395	.0402	9.0	8.6	3.4	3.3	2.5	2.4	.0315	.0333	8.8	8.1	3.0	3.0	2.2	2.3
.0331	.0390	8.9	8.8	3.1	3.4	2.3	2.5	.0287	.0302	8.2	8.3	3.0	3.0	2.2	2.3
.....	.0330	.....	8.1	.....	3.2	.....	2.4	.....	.0202	.....	6.8	.....	2.6	.....	1.8
.....	.0233	.....	7.0	.....	2.7	.....	2.0								

EFFECT OF REMOVING THE AWNS FROM HANNCHEN BARLEY AT ABERDEEN, IDAHO

Both the material and the conditions were more favorable for satisfactory investigations at Aberdeen than in Minnesota.

The Hannchen is a 2-rowed, awned variety of barley that grows very well under irrigation. The lateral florets are infertile, and this removes the complication of prolonged flowering and the great range of variation which is present when the small lateral kernels are developing. The normal development of Hannchen barley has been discussed in an earlier paper.[1]

The growth under irrigation in Idaho is much more uniform than that in Minnesota. There are few cloudy days and fewer days in which the humidity is at all high. Storms which break the culms are very rare, and diseases which affect the leaves or culms are entirely negligible.

[1] HARLAN, Harry V. OP. CIT.

The samples at Aberdeen consisted of at least two spikes. Just after flowering, when the kernels were small, three spikes were used. In Table IV only two of these are reported because the inclusion of the third makes the table even more cumbersome. In this table the steady growth of the kernel is apparent. Even when not averaged, the maximum kernel weights during the early part of the period constitute a very uniform series. The difference between the clipped and unclipped spikes becomes increasingly apparent as growth progresses.

The average weights and measurements in Table V are more easily studied than are the unsummarized data in Table IV. Table V gives the average by days. In some instances abnormal kernels have been thrown out, because they introduce variations that may as well be excluded. The kernels from the clipped spikes often exceed those of the normal spikes in weight and dimensions during the first week after flowering. As was the case in Minnesota, the normal spikes soon outstrip the clipped ones and maintain their advantage until maturity. The comparative development is illustrated in figures 7 and 8.

TABLE V.—*Average wet weight, length, lateral diameter, and dorsoventral diameter of kernels from normal and clipped spikes of Hannchen barley from flowering to maturity, at Aberdeen, Idaho, in 1916*

UNCLIPPED SPIKES

Date.	Wet weight.	Length.	Lateral diameter.	Dorsoventral diameter.	Date.	Wet weight.	Length.	Lateral diameter.	Dorsoventral diameter.
	Mgm.	*Mm.*	*Mm.*	*Mm.*		*Mgm.*	*Mm.*	*Mm.*	*Mm.*
July 10	3.8	3.35	1.37	0.93	July 22	51.2	10.17	3.58	2.52
11	5.8	4.53	1.53	.97	24	57.3	10.27	3.77	2.61
12	7.4	5.58	1.65	1.00	25	56.5	10.16	3.67	2.57
13	14.9	8.74	1.98	1.33	26	60.6	10.22	3.72	2.56
14	16.0	8.87	2.03	1.38	27	58.3	9.79	3.58	2.51
15	21.9	9.57	2.14	1.57	28	60.2	10.05	3.74	2.75
17	37.1	10.31	3.03	2.13	29	65.8	10.00	3.86	2.72
18	41.7	9.99	3.29	2.21	31	64 4	10.16	3.76	2.70
19	42.3	10.01	3.34	2.30	Aug. 1	61.5	9.92	3.75	2.72
20	43.5	10.27	3.34	2.30	2	51.9	9.61	3.47	2.59
21	46.9	10.35	3.51	2.36	3	52.2	9.57	3.47	2.58

CLIPPED SPIKES

July 10	3.3	3.00	1.27	0.85	July 22	47.1	9.80	3.47	2.27
11	6.7	5.13	1.55	.97	24	52.9	9.95	3.64	2.45
12	7.8	5.81	1.58	.92	25	52.3	9.99	3.50	2.41
13	13.8	8.28	1.89	1.27	26	57.4	9.98	3.59	2.50
14	18.3	9.41	2.12	1.48	27	52.6	9.66	3.45	2.44
15	21.6	9.46	2.24	1.57	28	55.6	9.72	3.60	2.58
17	31.9	9.49	2.91	1.95	29	59.6	9.71	3.68	2.57
18	36.4	9.71	3.05	2.07	31	56.4	9.73	3.61	2.54
19	37.1	9.56	3.22	2.15	Aug. 1	55.6	9.75	3.62	2.60
20	39.8	10.00	3.21	2.17	2	49.7	9.38	3.42	2.55
21	41.9	9.83	3.36	2.23	3	43.5	9.17	3.27	2.46

The graphs of the growth in length essentially coincide for six days after flowering. For some reason not apparent, the kernels in the normal spikes reach a greater length than those of the clipped spikes. This greater length is still in evidence at maturity. The difference is only ½

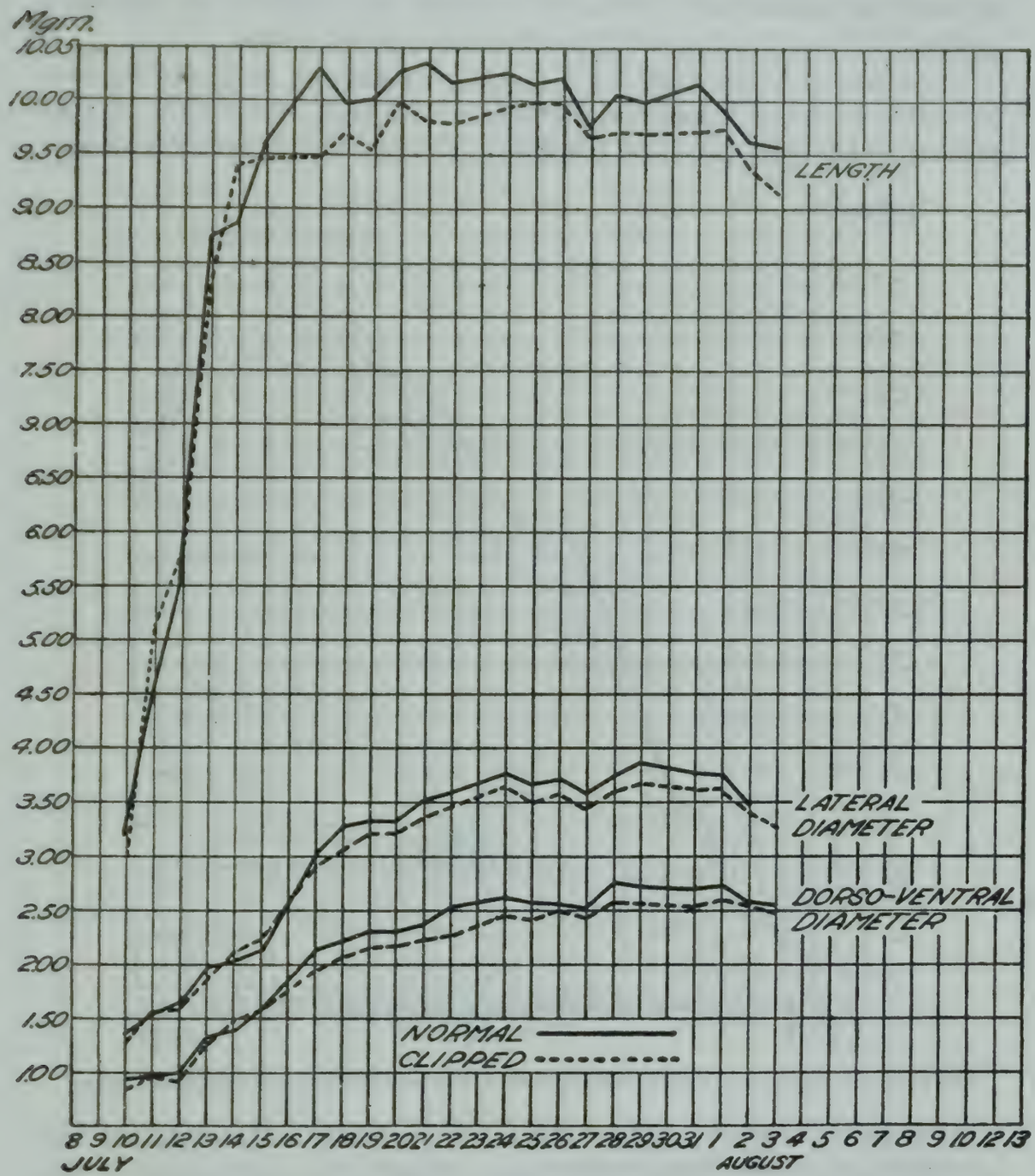

FIG. 7.—Graph showing growth in length, lateral diameter, and dorsoventral diameter of kernels of Hannchen barley in normal and clipped spikes.

mm., but it occurred in both Minnesota and Idaho. A part of the difference seems to have been due to the greater water content of the normal kernels, for the graphs of kernel lengths approach each other again at maturity.

At Aberdeen, the course of the development of the lateral diameter is much like that of the dorsoventral diameter. Seven or eight days after

flowering, the diameters of the normal kernels are larger than those from clipped spikes, and they then continue larger for the remainder of the period of development. In Minnesota, there is little difference between the kernels of the two classes of spikes until near maturity. As maturation approaches, the normal kernels are found to be uniformly greater in diameter than are those from the clipped spikes.

The graph of the wet weight is much more uniform at Aberdeen than at St. Paul. As in Minnesota, there is no difference between the clipped and normal spikes in the first few days. The period of equality is shorter

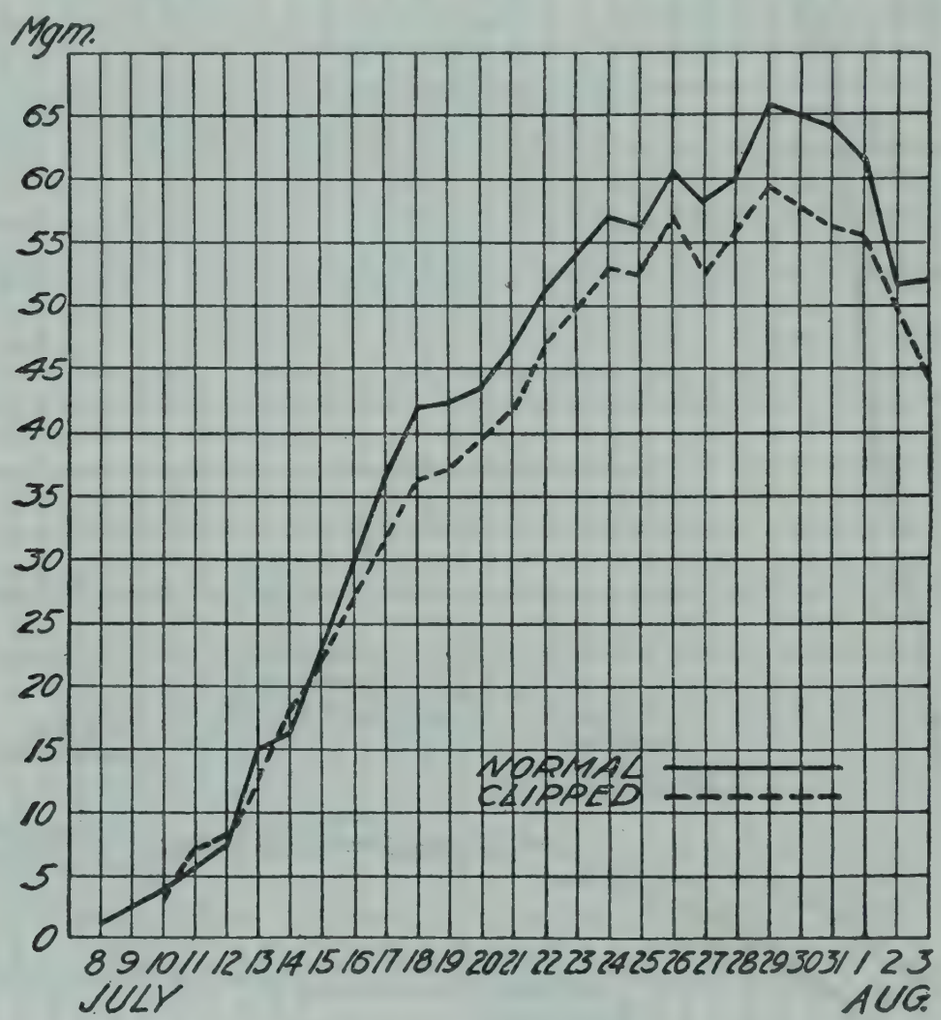

FIG. 8.—Graph showing wet weight of kernels of Hannchen barley from normal and clipped spikes.

at Aberdeen, however. After July 15 the average wet weight of the kernels from clipped spikes here never equals the wet weight of the kernels from normal spikes.

The wet weight includes a variable amount of water, which increases during the first half of the growing period and decreases during the second half. For this reason the curve of the wet weight differs greatly from the curve of the dry weight. The dry weights are shown in figure 9. In Minnesota, the trend of increase in dry weight was quite uniform, as was shown in figure 3. In Idaho, the graph of the dry weight is almost a straight line. It would seem that in both the normal and clipped

spikes the rate of growth was very nearly at its maximum. If this is true, the maximum of the clipped is less than that of the normal spike, for after July 15 the dry matter per kernel is always less.

The percentage and weight per kernel of the dry matter are given in detail in Table VI. This table also includes the data on water, nitrogen,

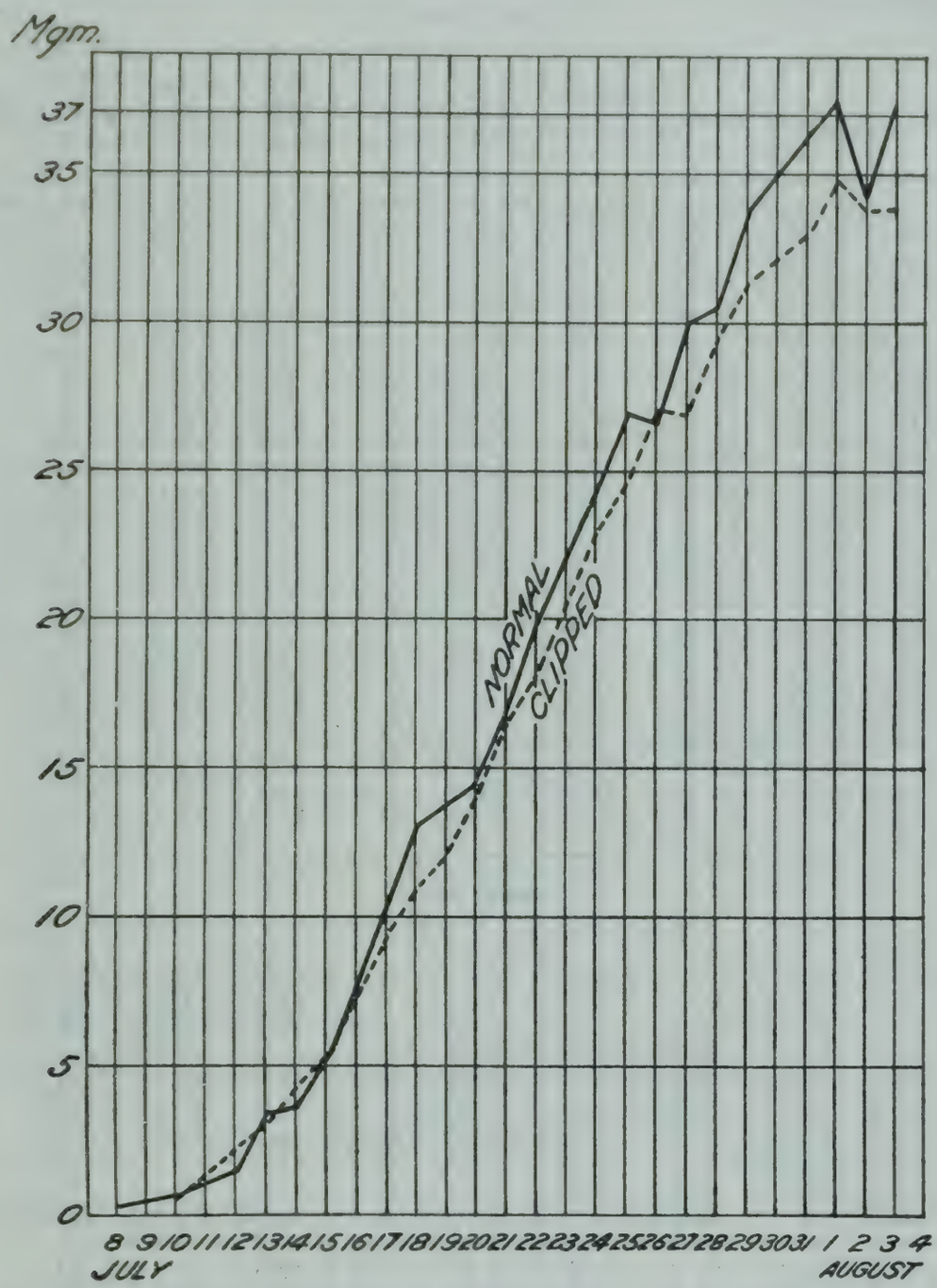

FIG. 9.—Graph showing dry matter in kernels of Hannchen barley from normal and clipped spikes.

and ash. These figures were obtained from the analyses of the samples reported in Tables IV and V. Most of the data on the percentages of the various substances have not been included in the figures. An inspection of the tables shows a surprisingly uniform decrease in the percentage of water and, of course, an equally uniform increase in the percentage of

dry matter. The difference between the percentage of materials present in the kernels of normal and clipped spikes is necessarily in direct relation to the actual quantities.

TABLE VI.—*Average percentage and weight per kernel of dry matter, water, nitrogen, and ash in kernels from normal and clipped spikes of Hannchen barley at Aberdeen, Idaho, in 1916*

NORMAL SPIKES

Date.		Dry matter.	Water.	Nitrogen in dry matter.	Ash in dry matter.	Wet weight per kernel.	Dry weight per kernel.	Water per kernel.	Nitrogen per kernel.	Ash per kernel.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*
July	8	20.48	79.52	.....	7.46	1.4	0.3	1.1	.....	0.02
	10	18.18	81.82	7.33	3.40	3.8	.7	3.1	0.05	.02
	11	19.23	80.77	4.61	4.21	5.8	1.1	4.7	.05	.05
	12	19.10	80.90	4.16	5.47	7.4	1.4	6.0	.06	.08
	13	22.03	77.97	3.56	4.33	14.9	3.3	11.6	.12	.14
	14	22.76	77.24	3.15	3.74	16.0	3.6	12.4	.11	.13
	15	23.87	76.13	2.94	3.69	21.9	5.2	16.7	.15	.19
	17	28.41	71.59	2.33	3.06	37.1	10.5	26.6	.24	.32
	18	31.06	68.94	2.01	3.21	41.7	13.0	28.7	.26	.42
	19	32.47	67.53	1.91	3.52	42.3	13.7	28.6	.26	.48
	20	33.21	66.79	1.80	3.45	43.5	14.4	29.1	.26	.50
	21	36.21	63.79	1.92	2.87	46.9	17.0	29.9	.33	.49
	22	38.92	61.08	1.93	2.63	51.2	19.9	31.3	.38	.52
	24	42.38	57.62	1.97	2.50	57.3	24.3	33.0	.48	.61
	25	47.59	52.41	2.02	2.56	56.5	26.9	29.6	.54	.69
	26	43.96	56.04	2.06	2.45	60.6	26.6	34.0	.55	.65
	27	51.37	48.63	1.83	2.60	58.3	29.9	28.4	.55	.78
	28	50.69	49.31	2.06	2.35	60.2	30.5	29.7	.63	.72
	29	50.99	49.01	2.03	2.32	65.8	33.6	32.2	.68	.78
	31	56.01	43.99	2.33	2.41	64.4	36.1	28.3	.84	.87
Aug.	1	60.96	39.04	2.17	2.20	61.5	37.5	24.0	.81	.83
	2	65.81	34.19	2.07	2.30	51.9	34.2	17.7	.71	.79
	3	71.91	28.09	2.25	2.25	52.2	37.5	14.7	.84	.84

CLIPPED SPIKES

July	10	17.8	82.2	5.43	6.63	3.3	0.6	2.7	0.03	0.04
	11	19.0	81.0	4.14	4.17	6.7	1.3	5.4	.05	.05
	12	28.0	72.0	3.73	4.80	7.8	2.2	5.6	.08	.11
	13	21.6	78.4	3.52	4.28	13.8	3.0	10.8	.11	.13
	14	23.5	76.5	3.04	4.08	18.3	4.3	14.0	.13	.18
	15	24.6	75.4	2.56	3.76	21.6	5.3	16.3	.14	.20
	17	29.2	70.8	2.59	3.36	31.9	9.3	22.6	.24	.31
	18	30.1	69.9	2.02	3.18	36.4	11.0	25.4	.22	.35
	19	32.4	67.6	2.00	2.89	37.1	12.0	25.1	.24	.35
	20	35.3	64.7	2.03	3.00	39.8	14.0	25.8	.28	.42
	21	39.4	60.6	2.03	2.93	41.9	16.5	25.4	.33	.48
	22	38.5	61.5	1.90	3.00	47.1	18.1	29.0	.34	.54
	24	43.3	56.7	1.97	2.69	52.9	23.0	29.9	.45	.62
	25	47.1	52.9	2.06	2.54	52.3	24.6	27.7	.49	.62
	26	47.2	52.8	2.06	2.80	57.4	27.1	30.3	.56	.76
	27	51.2	48.8	2.10	2.45	52.6	26.9	25.7	.56	.66
	28	52.8	47.2	2.15	2.39	55.6	29.4	26.2	.63	.70
	29	52.6	47.4	2.15	2.48	59.6	31.3	28.3	.67	.78
	31	58.4	41.6	2.06	2.08	56.4	32.9	23.5	.68	.68
Aug.	1	62.5	37.5	2.17	2.27	55.6	34.8	20.8	.76	.79
	2	67.9	32.1	2.24	2.31	49.7	33.7	16.0	.75	.78
	3	77.6	22.4	1.98	2.26	43.5	33.8	9.7	.67	.76

The ash was determined in more organs at Aberdeen than at St. Paul. The percentage of ash in the rachis, paleae, and awns is shown in figure 10, as well as the ash in the kernel. The analysis of the other structures throws much light on the problem. The awn contains a surprising amount of ash. At flowering time 10 per cent of its dry weight is ash, while at maturity 33 per cent of the dry weight is ash.

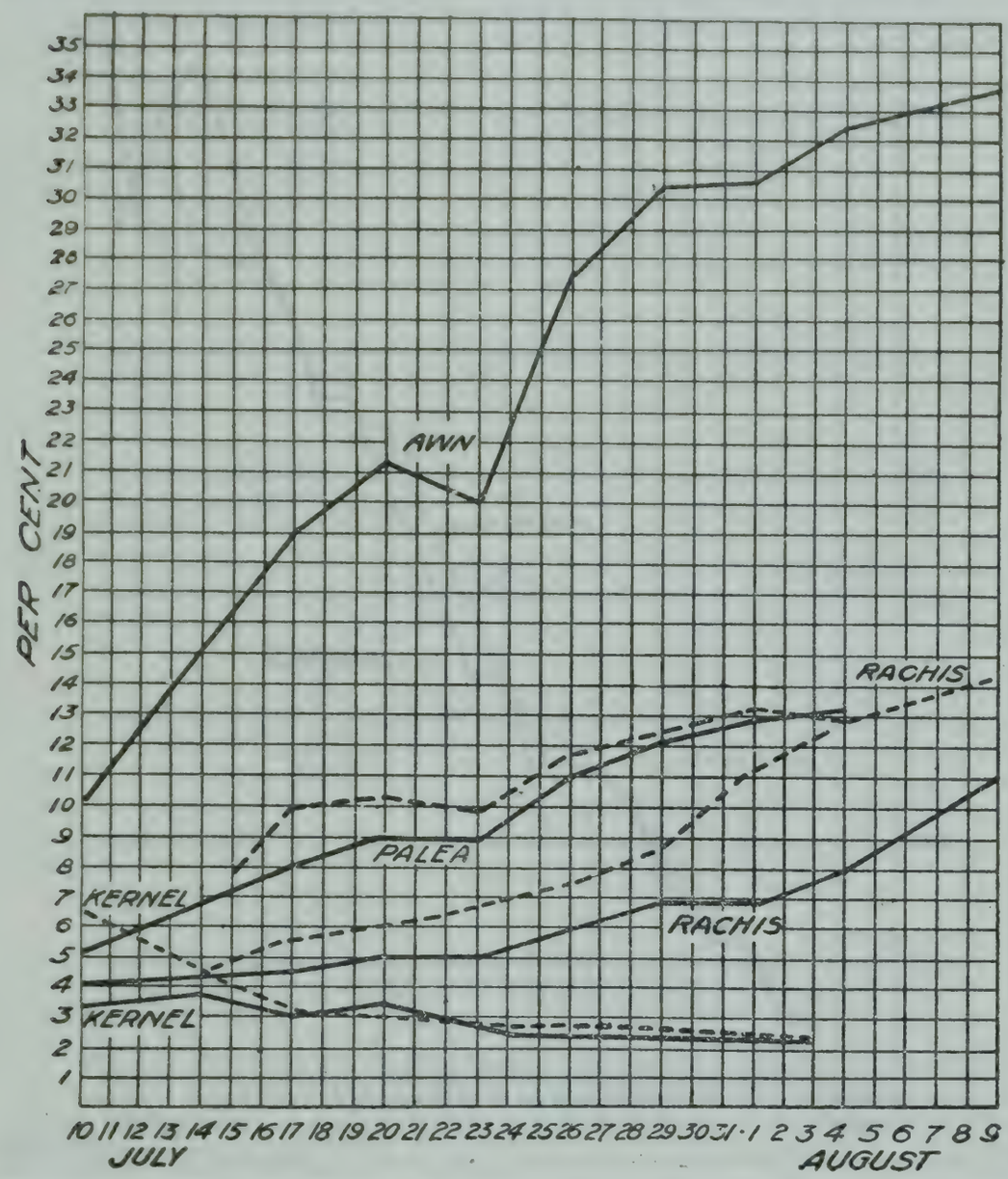

FIG. 10.—Graph showing percentage of ash in the kernels, rachises, paleae, and awns of normal spikes of Hannchen barley and in the kernels, rachises, and paleae of clipped spikes.

The total amount of ash present is considerable. The percentage of ash in the kernels of the clipped spikes is about the same as in those of the normal spikes. The paleae of the clipped spikes contain more ash than those of the normal spikes.

It is in the rachis that the greatest and most significant difference occurs. The rachises of the clipped spikes contain 25 per cent more ash than the rachises of the normal spikes. It would seem that much

of the mineral content that usually goes into the awn remains in the rachis of the clipped spike. These rachises were found to be brittle, while the normal ones were not. Both in Minnesota and in Idaho the clipped spikes had a tendency to shatter, while the normal spikes exhibit

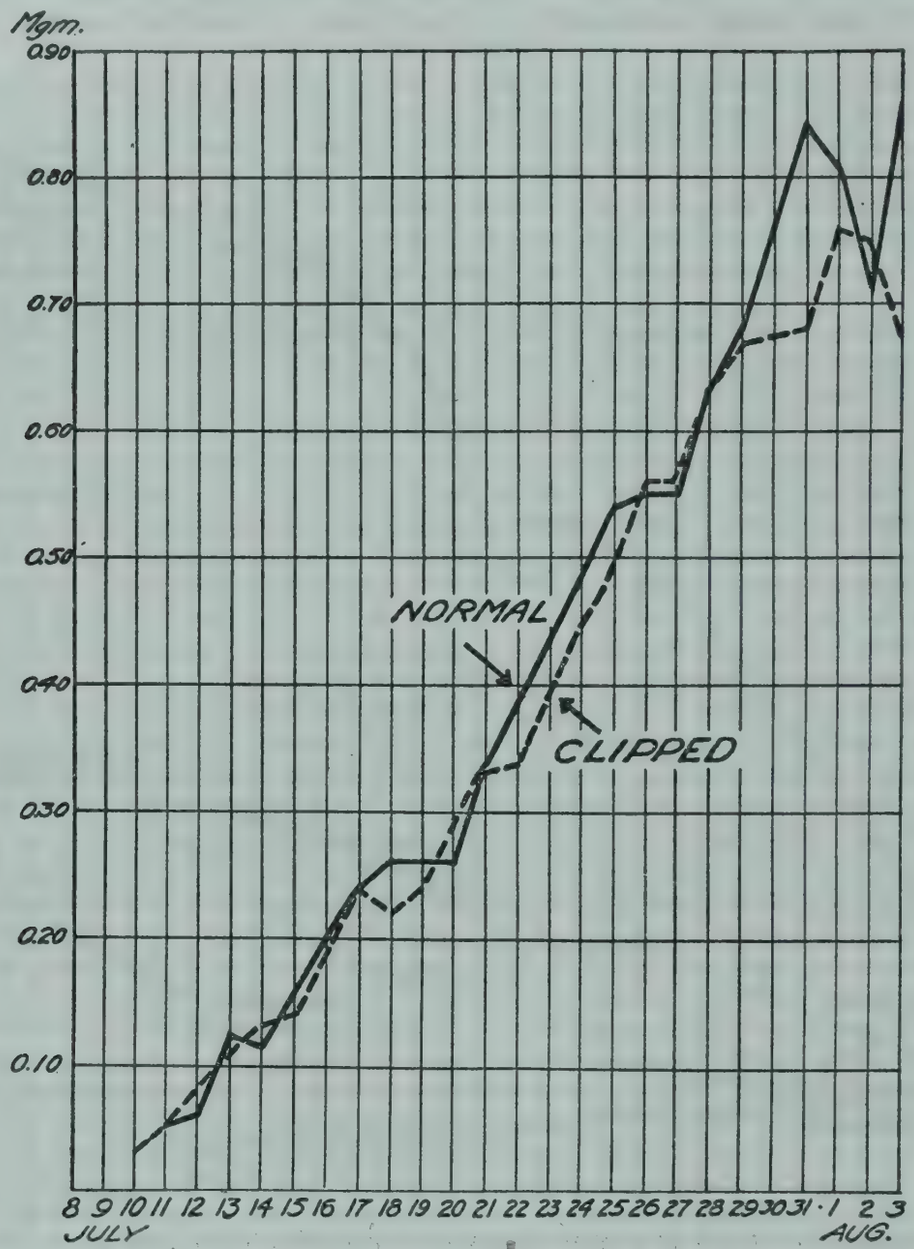

FIG. 11.—Graph showing total nitrogen in kernels of Hannchen barley from normal and clipped spikes.

no such tendency. The divergence in ash content is surprisingly large and widens consistently throughout the period of growth.

The increase in nitrogen per kernel in Idaho is similar to that found in Minnesota. The amount of nitrogen in the kernels from clipped spikes is almost as large as that in the kernels from normal spikes. The average is slightly less, but as a whole the content of nitrogen is nearly equal in the two, as may be seen in figure 11.

The difference in water content shown in figure 12 is more striking at Aberdeen than at Minnesota. After July 15 the kernels from clipped

spikes never contain as much water as those from normal spikes. This is in full accord with the results obtained at St. Paul, but the greater uniformity of the development at Aberdeen emphasizes the difference of behavior by removing the confusion of abnormal samples.

In a preliminary experiment conducted at Arlington Farm, Va., the relation of the length of the awn to the weight of kernel was studied. The awns increase in length from the base of the spike for about one-third the distance to the tip. The spikelets on the upper two-thirds of

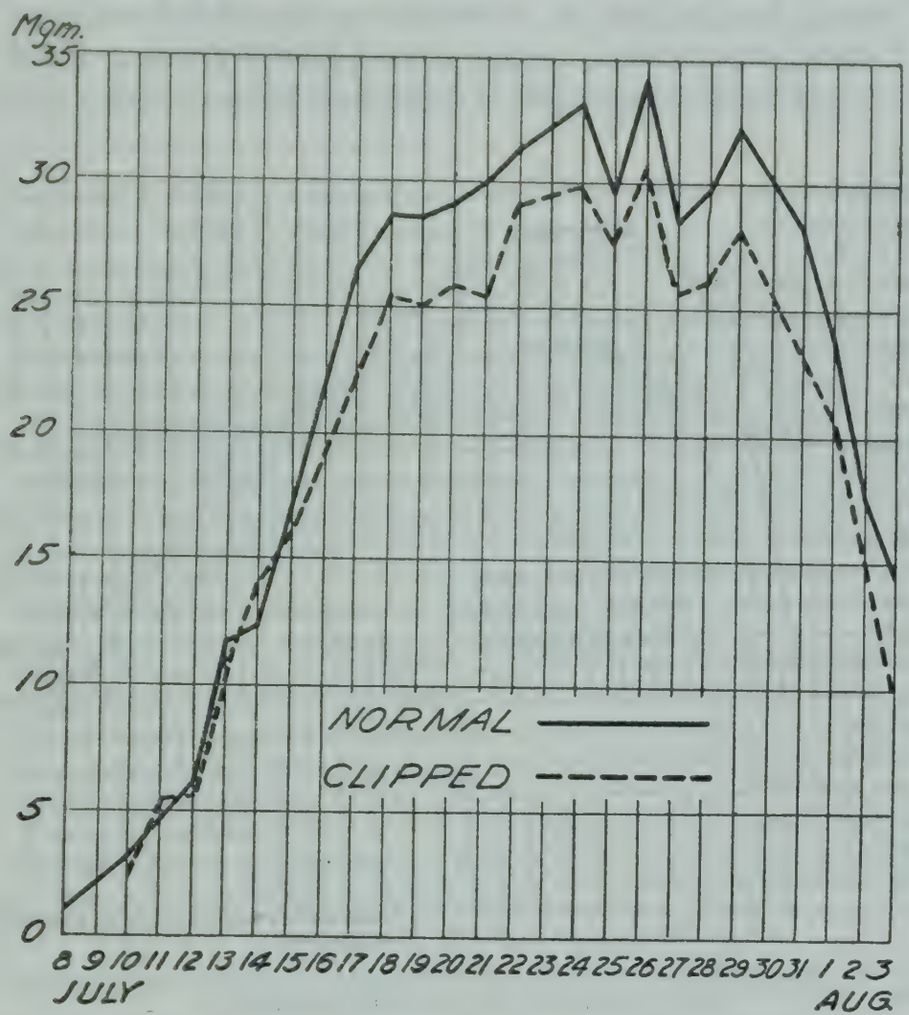

FIG. 12.—Graph showing water in kernels of Hannchen barley from normal and clipped spikes.

the spike exhibit a gradual decrease in awn length, the shorter awn occurring on the apical spikelet.

Figure 13 shows a composite spike resulting from the average of the data obtained. In this case the node numbers include both sides of the spike and are alternate. The weights used are the average of the kernels at two adjacent nodes. It will be seen in the figure that the greatest difference in weight results from the removal of the longest awns. The removal of the short awns near the tip affects the yield only slightly. If the curve of the clipped kernels is taken as showing that the normal peak due to nutrition occurs at about node 9 or 10, the greater length of awn on node 6 is seen to move the peak of the

kernels from awned spikelets nearer to the base of the spike than is the case in the clipped spikelets.

DISCUSSION OF RESULTS

The results in both Minnesota and Idaho have a direct bearing on the two chief field problems in the production of hooded and awnless barleys. These barleys have not yielded as well as the bearded sorts, and they have shattered.

The barleys from which the awns were removed did not give as high yield in these experiments as the awned plants growing beside them. This conforms to the experience of Zoebl and Mikosch, Schmid, Perlitus,

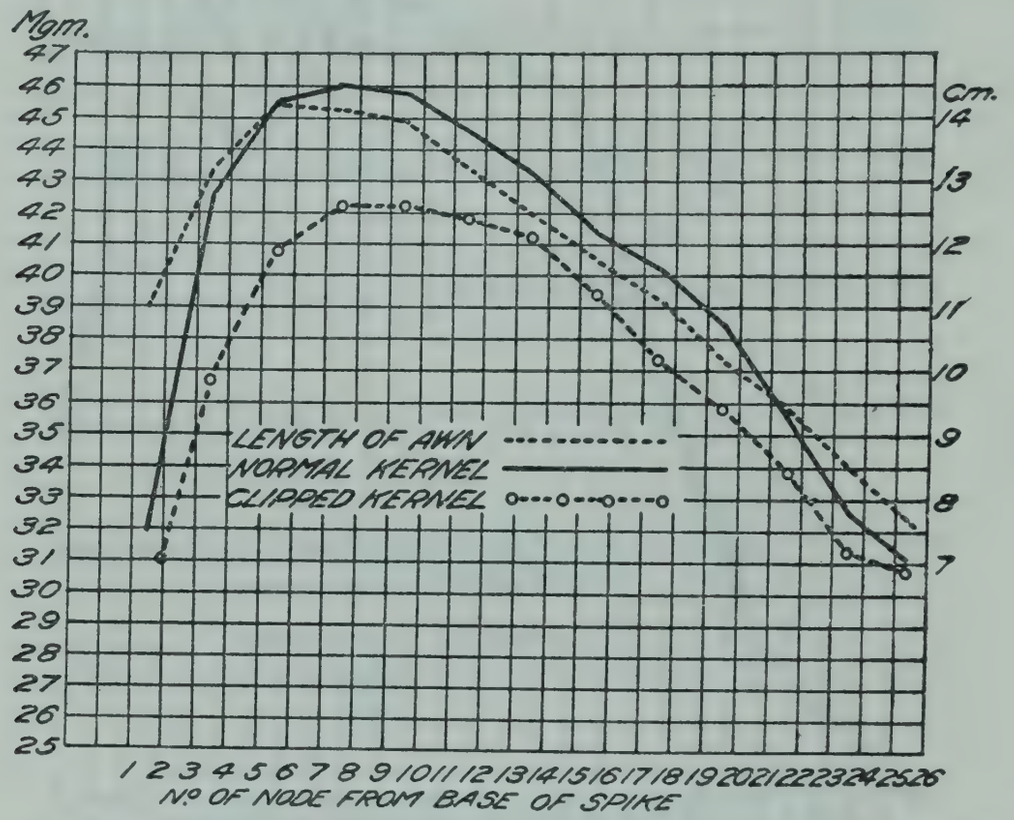

FIG. 13.—Graph showing relation of length of awn to weight of clipped kernels and unclipped spikelets on a 2-rowed barley grown at Arlington Farm, Va.

and some other investigators. In this study it was evident that the reduction in yield was not due to any injury to the plant, as the difference in growth was not apparent for several days after the awns had been removed. The early growth of the kernels in clipped and normal spikes was equally vigorous. It was only when starch infiltration became rapid that the awned spikes showed greater activity. The difference in ultimate weight was largely due to the difference in the quantity of starch present. There was little difference in the quantities of ash and nitrogen. Zoebl and Mikosch looked upon the awn as an organ of transpiration. Whether the reduction of transpiration alone is sufficient to account for the lower rate of starch production is a question. That transpiration has an influence on the behavior of the hooded

barleys is indicated in the field experiments. These barleys have proved relatively better in dry years on the northern plains than in wet years. In the "good" years the hooded varieties have been far inferior to the best bearded sorts, but in "bad" years they often have been better.

In any case, these two experiments show that the awn has a function, and the loss of the awn has resulted in a reduced yield.

The second field problem is that of shattering. The common hooded and awnless varieties have a tendency to shatter at maturity. The clipped spikes of Manchuria and Hannchen barleys showed a tendency in this direction; the normal spikes did not. The spikes from which the awns were removed proved to be fragile, and many of them fell to pieces as maturity approached.

An explanation of this behavior was found in the determination of ash in the awns, rachises, and paleae. The ash that normally went into the awn was deposited largely in the rachis of the clipped spikes. The additional ash seems to have been sufficient to cause the rachis to be brittle. It would seem that the awn also served as a place in which to store the excess of ash. More mineral matter probably is taken up in growth than is needed by the plant. There is no method of elimination. The extra mineral is deposited in cells which probably serve little purpose other than storage. The removal of tissues and organs containing cells which can be devoted to this end must, in itself, cause some derangement of the normal processes of development.

From the experiments conducted, it would seem that awnless and hooded barleys are limited by the loss of the awns. It appears that high yields are not to be expected from such varieties. It is to be expected that such sorts will shatter more than awned kinds. This has been the experience in breeding also. For the most part awnless hybrids have been brittle and of low yielding capacity. It is thought that there is little use in attempting to secure valuable awnless or hooded varieties by means of hybrids with most varieties. One possible method of breeding has been indicated by experiments not yet published. Some varieties of awned barley have normally a much lower content of ash in the rachis than others. It is possible that the progeny of crosses with these and the hooded sorts may yield well in semiarid climates and that they will not shatter. One or two such hybrids are now giving promise.

When the first elementary experiment conducted in Minnesota indicated the physiological difficulties in the way of producing desirable varieties of hooded and awnless barleys, work was amplified in another line. Several hundred hybrids with smooth awns have been produced and tested. Much of this work has been done in the cooperative experiments with the Minnesota Agricultural Experiment Station, but many strains have been tried elsewhere. Several of these give promise of good yielding capacity.

The awns of these hybrids are smooth. All the large scabrous teeth on the basal two-thirds of the awn have been eliminated. The tips of the awns are slightly rough, but this roughness is not sufficient to be objectionable to either growers or feeders of barley. Whether varieties of this type can be made to yield equally as well as the awned sorts remains to be determined.

SUMMARY

The removal of the awns from a barley spike has a marked effect on the development of the kernels of the spike.

Kernels from clipped spikes have smaller volume and a lower weight of dry matter at maturity than do those from normal spikes.

The difference is not due to the injury or shock of removing the awns; the kernels in the clipped spikes develop as rapidly as those in the normal spikes for several days after the awns are clipped.

About one week after flowering the deposit of dry matter in the kernels of the normal spikes begins to exceed that in the kernels of the clipped spikes. This is about the time that rapid starch infiltration begins.

The daily deposit of nitrogen and ash is more nearly equal in the two classes of spikes than is the deposit of starch.

In normal spikes at Aberdeen, Idaho, the awns contained more than 30 per cent of ash at maturity. When the awns were removed a part of this ash apparently was deposited in the rachis. The rachises of the clipped spikes contained about 25 per cent more ash than the rachises of the normal spikes.

The additional ash in the rachises of the clipped spikes probably was responsible for the tendency of these spikes to break. The indications are that the elimination of the awns results not only in lower yields but in shattering as well.

Hooded and awnless barleys generally yield less and shatter more than awned varieties, and there seem to be physiological reasons for this fact.

It may be possible to produce nonshattering hooded and awnless sorts by using parents which normally have a low percentage of ash in the rachises. It may be possible to obtain strains that will give good yields under arid conditions. Under humid conditions it is likely that the objections to the awns are more easily met by the use of strains with smooth awns, which, so far as known at present, have no physiological limitations.

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INVESTIGATIONS IN THE RIPENING AND STORAGE OF BARTLETT PEARS[1]

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INTRODUCTION

Physiological studies carried on in connection with the development, ripening, and storage of the Bartlett pear reveal the fact that the factors involved are somewhat different from those connected with the handling of most other fruits. Pears of this variety are not usually allowed to ripen on the tree but are picked as soon as they have attained suitable size for marketing and have reached the condition at which experience has shown they will ripen off the tree without shriveling. The exact tests and sizes that are usually used to determine this degree of development vary somewhat in different sections. Usually no fruit is harvested until it reaches 2¼ to 2⅜ inches in diameter; and such factors as the ease with which the stem separates from the branch, the plumpness of the fruit, or the degree to which the blossom end is smoothly rounded out, the extent to which the sides of the locules or seed cavities have drawn away from the seeds, and the depth to which the tissue crushes when pressed in by the finger are used to determine when the fruit has developed sufficiently to ripen in good condition if removed from the tree. Bartlett pears, when "ripe" off the tree, become soft and full yellow in color. This is the condition referred to by the term "ripe" in this paper.

In the Rogue River district of Oregon a mechanical pressure test (*9*)[3] has been used to some extent during the past year to determine the time of picking, but in the other pear districts of the Pacific coast the methods enumerated above have been followed.

If the pears are left on the trees until they are fully ripe, they are of a very inferior quality. Very often the inside is soft and decayed before

[1] This paper gives the result of a portion of the work carried on under the project "Factors Affecting the Storage Life of Fruit."

[2] The writer wishes to express appreciation to W. S. Ballard, Pathologist, United States Department of Agriculture, for the use of apparatus and for many helpful suggestions.

[3] Reference is made by number (italic) to "Literature cited," pp. 499–500.

the outside becomes yellow; or, if the inside does remain sound, it becomes coarse and granular and has a very inferior texture.

However, in most sections there is a period of from six weeks to over two months between the time at which the first commercial picking is now made and the time the fruit becomes ripe on the tree. Consequently, there is a possibility of considerable variation in the time at which the fruit may be removed from the tree in a green, firm condition and still ripen without shriveling. A consideration of these facts shows the importance of knowing what effect removing the fruit from the tree at varying times has on the keeping quality and on the comparative chemical composition from which the food value and eating quality may be judged.

REVIEW OF LITERATURE

Of much interest in this connection is the work of various investigators who have studied the chemical composition of pears. Some studies have been made of the influence of various environmental factors on the chemical composition of the fruit, which are of sufficient interest to warrant discussing in some detail.

Kulisch (7) concluded, among other things, that the age and shape of the tree and the size of the crops borne have an effect on the composition of the fruit. He found higher sugar content and larger size of fruit correlated in trees that had a light crop as compared to those with a heavy yield. He suggests that with a light crop there is an abundance of carbohydrate material for the full development of the fruit, while a heavy crop tends to draw from other organs of the tree, and even then the crop is cut down in size by an insufficient amount of carbohydrate material.

Ewert (4), in studying the influence on the fruit of the presence of well-developed seeds as compared to parthenogenetic fruit, made analyses of both kinds in several varieties of pears at intervals just previous to and including the time of ripening. In the late fall varieties with which he worked he found a marked increase in sugar as both seeded and seedless pears approached maturity, while the acids appeared to fluctuate somewhat. He found very little starch present in either seeded or seedless fruit. Cane sugar was very rarely present in ripe pears in the varieties studied. He found no very marked and constant differences due to the presence or absence of seeds, the results in this respect apparently varying with the variety.

Kelhofer (6) analyzed the various portions of the fruit of one variety, Siebenmannsbienen, for sugar, acid, and tannin. He found both sugar and acid to be higher in the central flesh portion as compared to the outer or peel region and the inner or core region. The greatest amount of tannin was in the outside or peel region, and there was very little in the core region. Analyses at succeeding dates from time of picking until soft ripe show a slight gain in sugars, a marked loss in acid, and a very marked

loss in tannin material. Analyses of the blossom-end, central, and stem-end portions of the fruit showed slightly more of both sugar and acid in the blossom end, with a slight decrease in the middle and somewhat greater decrease in the stem-end regions.

Ritter (*11*) carried on numerous investigations in the ripening processes of fruit. He found that growing fruit in the dark, so long as the fruit only was darkened, had no effect on the chemical composition; but where the surrounding branches and leaves were kept in darkness or semidarkness, there was a marked reduction, not only in carbohydrates but also in most of the other compounds in the fruit. His figures, however, are based on total grams of the various substances rather than on a percentage basis. He records a progressive increase in the amount of sugar present at successive dates throughout the season and a corresponding decrease in acid. These conclusions are based on work with several varieties of apples and pears.

Riviere and Bailasche (*12*) also record an increase in sugar and a decrease in acid in pears, based on analyses at intervals from June until the fruit is ripe. They found further (*13*) that defoliating spurs decreased the size of the fruit while the defoliation decreased the sugar content and increased the acid content slightly.

Analyses of pears have been made to a limited extent in this country. Dunbar and Bigelow (*3*) determined the acid present in a number of fruits, concluding that in Bartlett, Idaho, Le Conte, and Kieffer pears citric acid predominates, while for all other varieties malic is the main acid present.

Thompson and Whittier (*17*) identified and determined the proportion of the sugars present in a large number of fruits. In Bartlett pears they found levulose to predominate, with some sucrose and a relatively small percentage of glucose. They found, however, that the relative amounts of the various sugars present varied with the state of maturity of the fruit when analyzed.

Recently Cruess and Stone (*2*) made rather detailed studies in connection with Bartlett pear ripening in California. Fruit was secured from several sections of California at intervals during the picking season and was tested for size, soluble solids (Balling test), acids, starch, length of time to ripen from date of picking, and general quality of the ripened product. In general, the later pickings gave a slightly higher Balling reading than the earlier ones, and the same lots gave a somewhat higher reading when ripe than when fresh picked from the tree. The acid test tended to fluctuate a great deal, so much so that it is rather hard to see a correlation between time of picking and acidity. The amount of starch present in the last pickings, as shown by the iodin test, did not seem to be appreciably less than in the earlier pickings. There was a progressive shortening of the time required to ripen the fruit when stored at a constant temperature of 68° F. It was concluded, as a result of a season's work,

that Balling and starch tests were not satisfactory as a means of determining the proper picking conditions for pears.

Considerable work has been done in connection with the storage of Bartlett pears, and the effects of temperatures of storage and the methods of handling are fairly well established. Powell and Fulton (*10*) investigated the effect of storing of Bartlett and Kieffer pears under different temperatures and with different methods of handling. The Bartletts were grown in western New York. The effect of wrapping was tested, and temperatures of 32° and 36° F. were used for storage. Storing immediately, as compared to leaving four days out of storage, was also tried. Fruit stored within 48 hours at 32° kept in prime condition for six weeks, while that delayed four days showed considerable loss in the same length of time. Bartlett pears stored at 32° kept longer and in much better condition than those stored at 36°. Small, well-ventilated packages gave better results than barrels. Wrapped fruit kept in better condition than unwrapped lots. It was found that if the fruit is not too ripe when removed from low temperature storage it will remain sound as long after being removed as will fruit in the same degree of maturity that has not been stored at low temperatures.

Stubenrauch and Ramsey (*15*), working with precooling and storage in the Rogue River Valley of Oregon, picked fruit at three different stages of maturity, packed it, and placed it in a precooling room at 20° F. The room was held at this temperature until the outer fruit in the packages reached 32°; then the room temperature was allowed to rise to 30° or 32°. Their conclusions were that the later picks gave much less physiological decay than the earlier ones, and that by allowing the fruit to remain on the trees fully two weeks longer than was usually done it is possible to hold fruit in storage four weeks at the temperature indicated, if stored promptly, then to ship in iced refrigerator cars and still have the fruit reach the market in good condition. At least 12 to 14 days are required to market fruit from the Rogue River Valley section, if the destination is Atlantic coast cities.

Lewis, Magness, and Cate (*8*) carried on picking and storage investigations in the Rogue River Valley during the summer of 1916. Bartlett pears from three orchards were picked at frequent intervals and the lots divided for the following types of storage: At 70° F. in both humid and dry, or ventilated, storage; at about refrigerator-car temperature, or from 50° to 60°; and in cold storage at 32° and 36°. The results obtained show that in the Rogue River Valley there is a marked increase in size of fruit from week to week even during the picking season, and delaying picking increased the size very markedly. The later pickings were of the highest quality when ripened up. There was a direct correlation between low temperature and length of storage season. A temperature of 32° gave a much longer period during which the fruit remained in good condition than did 36°, while 50° to 60° and 70° gave correspondingly shorter

storage seasons. For storage at 60° or above—that is, common storage—the earliest pickings gave the longest storage season; but when the lower temperature was used the maximum season was obtained in the later picks of more fully matured fruit. This agrees with Stubenrauch and Ramsey in their precooling work. No important correlation could be established between specific gravity of the juice and time of picking, or between starch, as shown by iodin test, and time of picking. Chemical analyses for sugar, acid, and moisture, made under rather unfavorable conditions, were also rather conflicting in results but showed a tendency toward an increase in sugar as the season advanced.

Further work (*16*) carried on in the Rogue River region gave further detailed evidence of marked increase in size of the fruit during the picking season. The influence of time of picking and temperature of storage upon keeping quality correlated closely with that obtained the year before. A "pressure test," or the measure of the amount of pressure necessary to make a depression of certain size in a pear at various stages of development and maturity was followed through the season; and a marked correlation was established between the time of picking and the resistance of the fruit to pressure, the resistance growing less the longer the fruit remained on the tree.

Some work has been done recently on the effect of storing Bartlett pears at high temperature. Shamel (*14*) placed a box of pears in a lemon-curing room, held at a temperature of about 90° F. and at a humidity averaging 85° to 90°. The pears kept perfectly and without ripening for a month. Upon removal from the storage they ripened normally and were of good quality. Shamel attributed these results to the high humidity.

Taylor and Overholzer (*16*), following Shamel's work, stored small lots of Bartletts at temperatures ranging fron 69° to 104° F., with one lot at 32° storage as a control. High humidity and normal dryness of air were compared at each temperature. Fruit held at 69° to 85° ripened most quickly. When the storage temperature was above 85°, the ripening of the fruit was retarded. Fruit stored at 104° was two to three weeks later in ripening than that stored at 85°. Humidity had no effect other than that of preventing shriveling at the high temperatures.

From a summary of all the storage work that has been done on Bartlett pears it is apparent that the lower the temperature used, down to 31° or 32° F.—the lowest temperatures of storage used in these experiments—the longer the storage season will be. Most rapid ripening is attained at a temperature of 70° to 80°, while either higher or lower temperatures tend to retard ripening. It is not definitely known just why these higher temperatures should retard ripening, but it is of interest to note that many of the processes concerned with the ripening of fruit are chemical reactions brought about by enzym action. It is well known that there are minimum, optimum, and maximum temperatures for enzym

action; and it is an interesting possibility that the temperatures which retard ripening may be sufficient to inhibit enzyms. It is well known that plant growth, in which many of the processes are similar to those in the ripening fruit, is inhibited by high temperatures.

From the foregoing summary of the work that has been done on pear ripening and storage it is apparent that for the varieties tested there has generally been found an increase in sugars as the season advanced. The data regarding acid are rather more conflicting. The work on storage and time of picking of Bartletts has shown that the later pickings have given a longer low temperature storage season and a higher quality in the ripened product.

In this investigation it has been the purpose to make a careful study of the changes that take place in Bartlett pears from the Pacific coast regions during the time they are developing, including the commercial picking season and extending somewhat beyond it. The effect of the time of removing the fruit from the tree on its content of acid, sugar, starch, and moisture has been studied. It has also been the purpose to determine the changes that take place in the fruit between the time of picking from the tree and the time the fruit is in prime eating condition—that is, soft and full yellow ripe—and to see if the temperature at which the fruit is held during ripening has any appreciable effect upon its composition.

The principal part of the work was carried on with fruit from two important pear sections of California. One lot was secured from an orchard at Sacramento. This orchard is typical of the large Sacramento River pear district and is grown on reclaimed, irrigated soil adjacent to the river. The summer here is warm and dry, but abundant water is available for irrigation.

Fruit from a ranch near Suisun, Calif., was also used. This section is slightly higher and nearer the coast than the Sacramento district. Fruit from this section is quite representative of much of the central California pear region away from the Sacramento River. Fruit from both of these orchards was picked at frequent intervals from early June, almost a month before commercial picking started, until after the close of the shipping season.

For purposes of comparison, fruit was secured from Medford, Oreg. This is representative of well-grown fruit on heavy soil in a typical irrigated Rogue River Valley orchard. Three boxes were secured from this orchard, one picked July 19, about 18 days before commercial picking started, one August 8, representing the beginning of the shipping season, and one August 28, at the end of the shipping season for Bartletts.

Fruit was also secured from the Selah section of the Yakima Valley, Wash. The first fruit from this section was picked July 28, 1919, followed by a shipment August 13, at the beginning of the shipping

season. Fruit picked August 23 was representative of the late shipments. Because of trouble from the fruit breaking down while in transit in former years, shippers from this section endeavored to reduce the later shipments to a minimum, and much of the late fruit was marketed through the canneries. This accounts for the relatively short shipping season in this section.

The fruit was picked, packed, and shipped by express to the laboratory at Watsonville, Calif. Fruit from Suisun usually arrived in 1 day, from Sacramento in 1½ days, from Medford, Oreg., in 2 days, and from Selah, Wash., in 4 days. Consequently, a somewhat longer time elapsed between the time of picking and time of storing the Washington pears than was the case with other districts.

As soon as the fruit arrived at the laboratory, each picking was divided into four lots. One lot was sampled for immediate analysis, while the remaining three were placed in storage until ripe. One of these was held at from 65° to 70° F., approaching the temperature at which pears ripen most quickly. One was stored at a fluctuating temperature of 34° to 50°, averaging a little above 40°. This is not far from representative of conditions in an iced refrigerator car in transit, although at a slightly lower temperature. The third lot was held at a temperature ranging from 28° to 32° and representing about the minimum temperature at which the pears could be held without the formation of ice in the fruit. The average temperature was slightly below 30°, though some of the time it was down to 28°, with no apparent bad results. It was impossible to allow the fruit to reach full maturity in this storage because of the length of time it would require, so part of all lots was removed October 14, after being from 1½ to 3½ months in storage. It was allowed to ripen at laboratory temperature and was analyzed.

In this way it has been possible to get a comparison between fruit when it is fresh picked from the tree and the same lot of fruit when ripened at temperatures approximating 70°, 40°, and 30° F. In planning the work it was not the thought to develop the storage phase primarily, but it has been possible to compare the length of the storage season with results attained by other investigators.

ANALYTICAL METHODS

SAMPLING.—A sample comprising portions of 15 pears was used for each lot. The fruit was first halved longitudinally and then a section from two opposite sides was removed, the cut being made from the core outward so that a fair proportion of the tissue from all the different regions of the fruit was secured. Any adhering portions of core were removed, and the peel was taken off with as little of the fleshy portion as possible. Sections of sufficient size were taken from each of the 15 pears to make a composite sample of over 300 gm.

The whole sample was then run through a sampling press, constructed on the principle described by Clark (*16*). In this press the tissue was forced through fine perforations which left it in a finely divided state. It was then very thoroughly mixed by stirring and carefully weighed out in six 50-gm. portions. By this method there is a very slight loss in moisture due to evaporation; but by working as rapidly as possible after the sample is run through the press this loss is reduced to a minimum and is closely comparable in all cases. The method of sampling employed was very satisfactory from the standpoint of giving close checks on such duplications as were run.

SUGARS AND ACID-HYDROLYZABLE REDUCING MATERIAL.—Duplicate samples were prepared for these determinations, but only one was run through. The 50-gm. samples were covered with about 100 cc. of 95 per cent alcohol, 3 to 5 drops of ammonia were added to neutralize the acid, then the samples were immediately put on the steam bath and boiled vigorously for a few minutes. Most of the excess ammonia was driven off by the boiling. Preliminary tests of glucose solution treated in this manner with dilute ammonia showed no measurable breaking down of the sugar. The alcohol was then filtered off through an alundum thimble, and the sample was extracted with alcohol in a Soxhlet extractor for about 12 hours. The extract was then added to the original alcohol filtrate, and the sample was made up to 500 cc. with distilled water. Fifty cc. of this were cleared with neutral lead acetate and were made up to 250 cc. The excess lead was removed, and the sugars were determined in 20 cc. of the cleared solution, according to Mathews's[1] modification of Munsen and Walker's and Bertrand's methods. Duplicate titrations with permanganate solution were checked to within 0.2 cc.

Fifty cc. of the cleared solution were inverted in 3.5 per cent hydrochloric-acid solution, standing about 20 hours at room temperature. The total reducing substances were then determined in this solution.

The residue in the thimble from the Soxhlet extraction was removed quantitatively, was dried, and 125 cc. of 2.5 per cent hydrochloric acid were added for hydrolysis by the modified Sachsse method.[2] Reducing substances were determined as outlined above and were figured as dextrose. This alcohol-insoluble acid-hydrolizable material probably consists mainly of starch, galactans, hemi-celluloses, and pectin in the green fruit fresh from the tree. In the ripe fruit there is no starch present, as shown by the iodin test, and the reducing material must come almost entirely from such sources as the galactans, hemicellulosses, and pectins. Much of the reducing material

[1] MATHEWS, A. P., PHYSIOLOGICAL CHEMISTRY...ed. 2, p. 994. New York, 1916.

[2] WILEY, H. W., ed. OFFICIAL AND PROVISIONAL METHODS OF ANALYSIS, ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. As compiled by the committee on revision of methods. U. S. Dept. Agr. Bur. Chem. Bul. 107 (rev.), p. 53. 1908.

formed may be pentoses, but calculating all reducing substances as dextrose gives a satisfactory comparison.

ACID.—Two 50-gm. portions of the sample were weighed into beakers, about 150 cc. of distilled water were added, and this was immediately boiled to render the cells permeable. After the portions cooled they were made up to 500 cc., 2 cc. of toluol were added to each as a preservative, and they were allowed to stand with frequent shaking for 3 days. One hundred cc. of the supernatant liquid were then drawn off for titration with *N/10* sodium hydroxid. Duplicate samples made by this method checked very closely.

DRY WEIGHTS.—Two 50-gm. samples were weighed directly into evaporating dishes. These were then dried down on the steam bath sufficiently to prevent growth of microorganisms; then when a sufficient number accumulated, they were put in a vacuum oven at 70° F., dried five days, removed and weighed, then returned to the oven for two days. During the last two days the decrease in weight was about 50 mgm.; but, since all lots were run in exactly the same manner, the results are closely comparable. All dry weight determinations were made in duplicate, and the figures presented are averages. While considerable variation occurs in successive determinations, duplicates in all cases checked very closely.

PRESENTATION OF DATA

The results of all the analyses are summarized in Tables I to IV. Table I includes all the data of fruit from the Sacramento orchard, Table II those from the Willota Orchard at Suisun, Calif., Table III those from Medford, Oreg., and Table IV those from Yakima, Wash.

TABLE I.—*Chemical analyses of Bartlett pears from Sacramento River Valley, Calif., in 1919*

Lot No.	Date of picking.	Acid as malic.				Reducing sugar as glucose.				Total sugar as glucose.				Alcohol-insoluble, acid-hydrolyzable substances as glucose.				Dry weight.			
		Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.		
			70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	June 12	0.3442	0.2561	0.2902	.....	3.70	6.28	5.11	.....	4.40	7.15	5.61	.....	3.76	2.15	2.37	.....	16.60	16.93	15.86	.....
2	18	.3380	.3032	.2869	.....	3.86	6.55	5.03	.....	4.32	7.40	6.13	.....	3.85	1.94	1.96	.....	16.57	15.87	14.99	.....
3	July 5	.3606	.3899	.3198	0.2640	5.40	7.43	6.31	6.50	6.00	8.37	7.00	7.77	3.77	1.67	1.76	1.56	16.03	15.72	15.20	16.07
4	12	.3319	.4084	.3334	.2514	5.53	7.43	6.50	6.56	6.07	8.34	7.05	8.07	3.40	1.71	1.99	1.81	16.17	15.71	15.94	16.87
5	23	.3258	.3954	.3278	.2897	6.20	7.39	6.40	6.60	6.65	8.87	7.33	8.22	2.73	1.56	1.87	1.52	16.02	15.98	15.54	15.99
6	Aug. 13	.2568	.2630	.2554	.2394	7.12	7.64	7.70	7.56	8.35	10.10	9.40	9.72	2.36	1.20	1.24	1.33	17.37	15.98	17.15	17.18

TABLE II.—*Chemical analyses of Bartlett pears from Suisun, Calif., in 1919*

Lot No.	Date of picking.	Acid as malic.				Reducing sugar as glucose.				Total sugar as glucose.				Alcohol-insoluble, acid-hydrolyzable substances as glucose.				Dry weight.			
		Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.		
			70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	June 10	0.4288	0.3176	0.3215	.....	2.48	4.55	3.62	.....	3.20	5.05	4.04	.....	3.87	2.95	3.05	.....	16.08	17.58	17.72	.....
2	July 1	.3100	.3106	.2264	0.2377	4.79	7.01	4.87	6.10	5.20	7.67	5.58	7.20	3.70	2.13	1.76	2.00	15.56	16.39	14.18	16.06
3	10	.2880	.2950	.....	.....	5.75	8.05	.....	.....	6.37	8.90	.....	.....	3.66	1.99	.....	.....	17.63	18.08	.....	.....
4	22	.2492	.2670	.2148	.1963	6.34	7.45	6.45	6.44	6.90	9.05	7.70	7.73	2.79	1.56	1.59	1.54	16.61	16.46	15.83	16.47
5	Aug. 6	.2301	.2486	.2107	.2024	6.78	7.63	6.95	7.75	8.22	9.98	8.67	9.20	1.94	1.04	1.18	1.23	15.50	17.31	15.40	16.20

TABLE III.—*Chemical analyses of Bartlett pears from Rogue River Valley, Oreg., in 1919*

Lot No.	Date of picking.	Acid as malic.				Reducing sugar as glucose.				Total sugar as glucose.				Alcohol-insoluble, acid-hydrolyzable substances as glucose.				Dry weight.			
		Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.		
			70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	July 19	0.3249	0.3908	0.3037	0.2798	5.59	7.39	6.38	6.60	6.07	8.19	7.15	7.60	3.20	1.55	1.64	.....	15.50	15.64	.....	15.91
2	Aug. 8	.3263	.3639	.3358	.3054	6.29	7.41	6.45	7.41	6.95	8.71	7.33	8.72	2.43	1.03	1.41	1.43	15.27	17.29	14.61	16.10
3	28	.3570	.3631	.3516	.3591	.....	7.95	7.87	7.98	.....	10.10	9.35	10.00	.....	1.35	1.44	1.43	17.28	17.70	17.34	17.95

TABLE IV.—*Chemical analyses of Bartlett pears from Yakima Valley, Wash., in 1919*

Lot No.	Date of picking.	Acid as malic.				Reducing sugar as glucose.				Total sugar as glucose.				Alcohol-insoluble, acid-hydrolyzable substances as glucose.				Dry weight.			
		Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.			Green fruit.	Same lot ripe after storage.		
			70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.		70° F.	40° F.	30° F.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	July 28	0.2790	0.2215	.....	0.2385	4.95	6.28	.....	5.65	5.28	6.95	.....	6.50	2.44	1.24	.....	1.51	14.10	14.40	.....	14.22
2	Aug. 13	.3510	.3800	0.3335	.2852	6.35	.....	6.74	6.86	6.80	.....	7.70	8.20	2.65	1.29	1.49	1.49	17.01	15.70	15.05	15.76
3	23	.....	.4435	.4510	.4360	.....	7.43	7.50	6.31	.....	9.07	8.65	9.35	.....	1.29	1.38	1.30	.....	16.88	17.02	17.24

For purposes of comparison and discussion, however, the results are also presented as a series of curves, in which it is possible to bring similar substances under the varied treatments into direct comparison.

INFLUENCE OF TIME OF PICKING UPON SUGAR CONTENT OF FRUIT

Figures 1 to 4, inclusive, summarize the data on the development of sugars in the fruit at the various intervals at which pickings were made

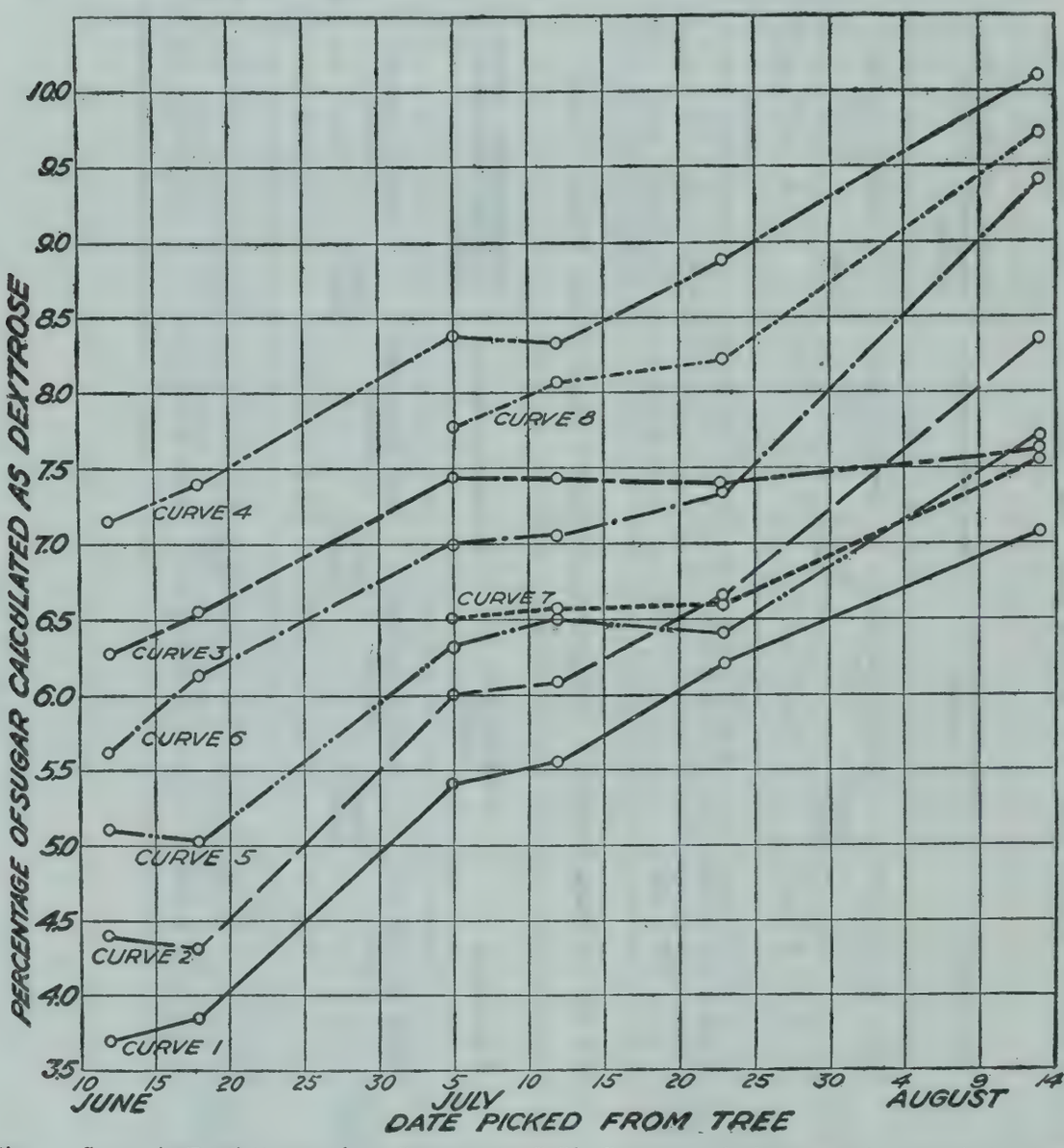

FIG. 1.—Sugars in Bartlett pears from Sacramento, Calif.: Curve 1, reducing sugars in green fruit when picked from the tree; curve 2, total sugars in green fruit when picked from the tree; curve 3, reducing sugars in collateral lots after ripening at 70° F.; curve 4, total sugars in collateral lots after ripening at 70°; curve 5, reducing sugars in collateral lots after ripening at 40°; curve 6, total sugars in collateral lots after ripening at 40°; curve 7, reducing sugars in collateral lots after ripening at 30°; curve 8, total sugars in collateral lots after ripening at 30°.

and the influence of various types of storage upon the sugar content of the fruit picked at these same intervals. Curve 1 in each figure represents the reducing material present, figured to percentage of green weight in the fruit fresh picked from the tree. According to Thompson

and Whittier (*17*) this consists mainly of levulose, but it has been figured as dextrose here because comparative results are of primary interest. Curve 2 represents the total sugar or reducing material after inversion, so that the distance between curves 1 and 2 represents the amount of

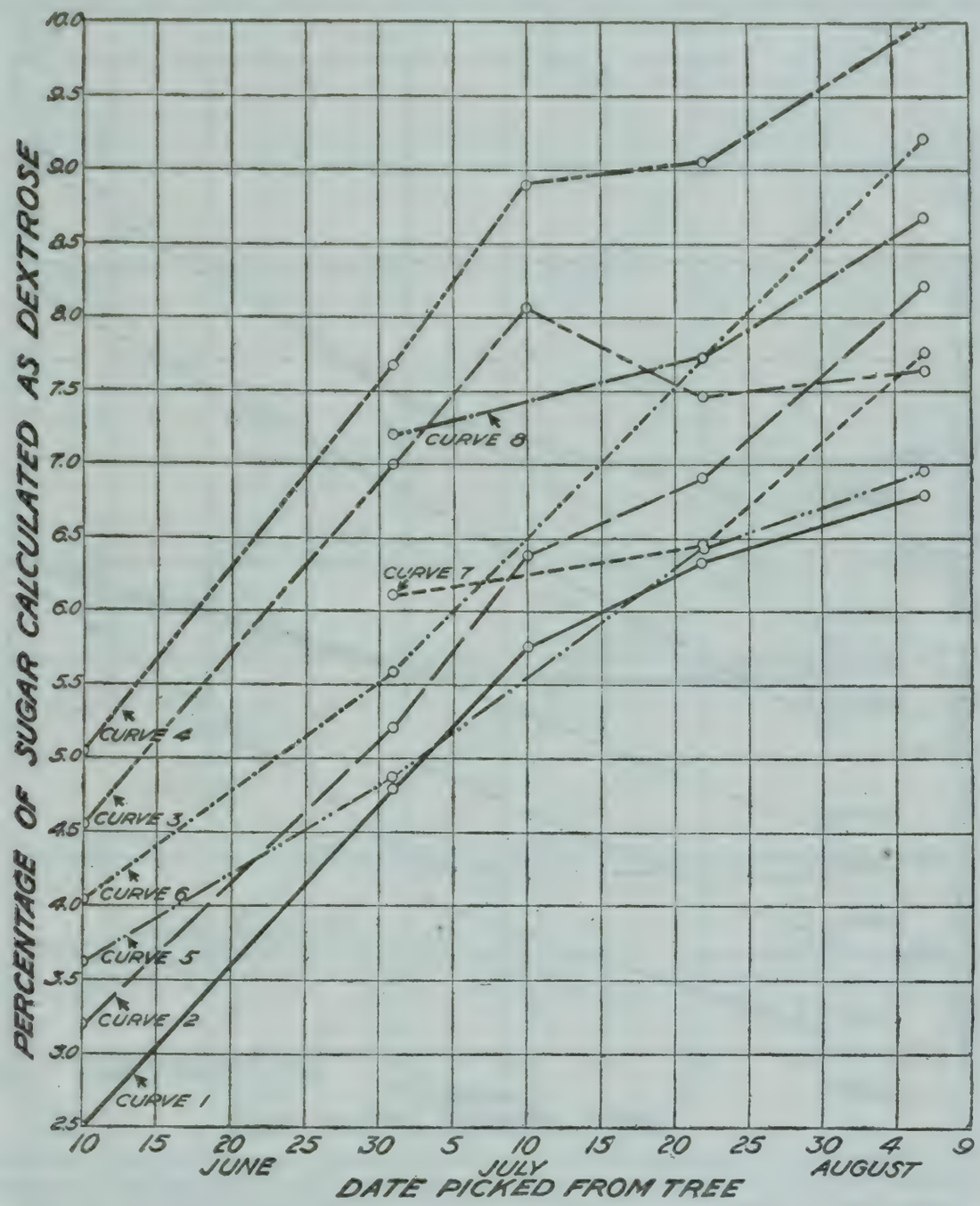

FIG. 2.—Sugars in Bartlett pears from Suisun, Calif.: Curve 1, reducing sugars in green fruit when picked from the tree; curve 2, total sugars in green fruit when picked from the tree; curve 3, reducing sugars in collateral lots after ripening at 70° F.; curve 4, total sugars in collateral lots after ripening at 70°; curve 5, reducing sugars in collateral lots after ripening at 40°; curve 6, total sugars in collateral lots after ripening at 40°; curve 7, reducing sugars in collateral lots after ripening at 30°; curve 8, total sugars in collateral lots after ripening at 30°.

sucrose present. There is in every case a marked increase in the amount of reducing sugar present at successive dates of picking. This increase is somewhat more rapid early in the season, although a distinct increase occurs as long as any pickings are made. It is unfortunate that it was

impossible to secure even later pickings to see if this increase in reducing sugar continues until the fruit is fully ripe on the tree.

The amount of sucrose remains nearly constant at less than 1 per cent throughout the early season. In the late season there was an increase in the amount of sucrose to 1½ per cent in the late picks of California

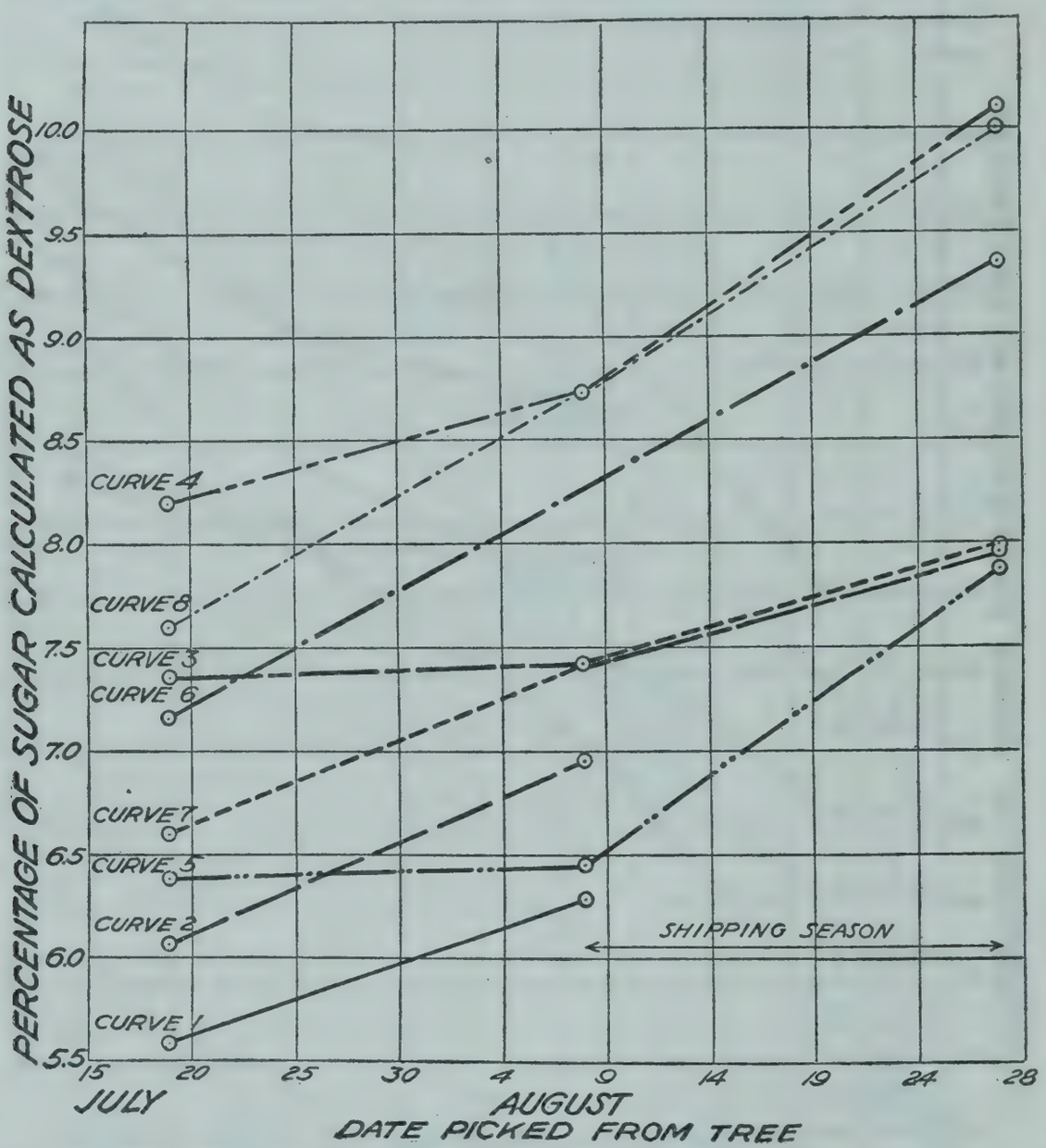

FIG. 3.—Sugars in Bartlett pears from Medford, Oreg.: Curve 1, reducing sugars in green fruit when picked from the tree; curve 2, total sugars in green fruit when picked from the tree; curve 3, reducing sugars in collateral lots after ripening at 70° F.; curve 4, total sugars in collateral lots after ripening at 70°; curve 5, reducing sugars in collateral lots after ripening at 40°; curve 6, total sugars in collateral lots after ripening at 40°; curve 7, reducing sugars in collateral lots after ripening at 30°; curve 8, total sugars in collateral lots after ripening at 30°.

fruit. The increase in sucrose in the late pickings is such that the increase in total sugar shows no falling off in rate up to the date of the last pickings secured. The less rapid increase in reducing sugar is counteracted by the increase in sucrose.

Curves 3 and 4 in each figure represent reducing and total sugar, respectively, when the fruit reached prime eating condition in a storage

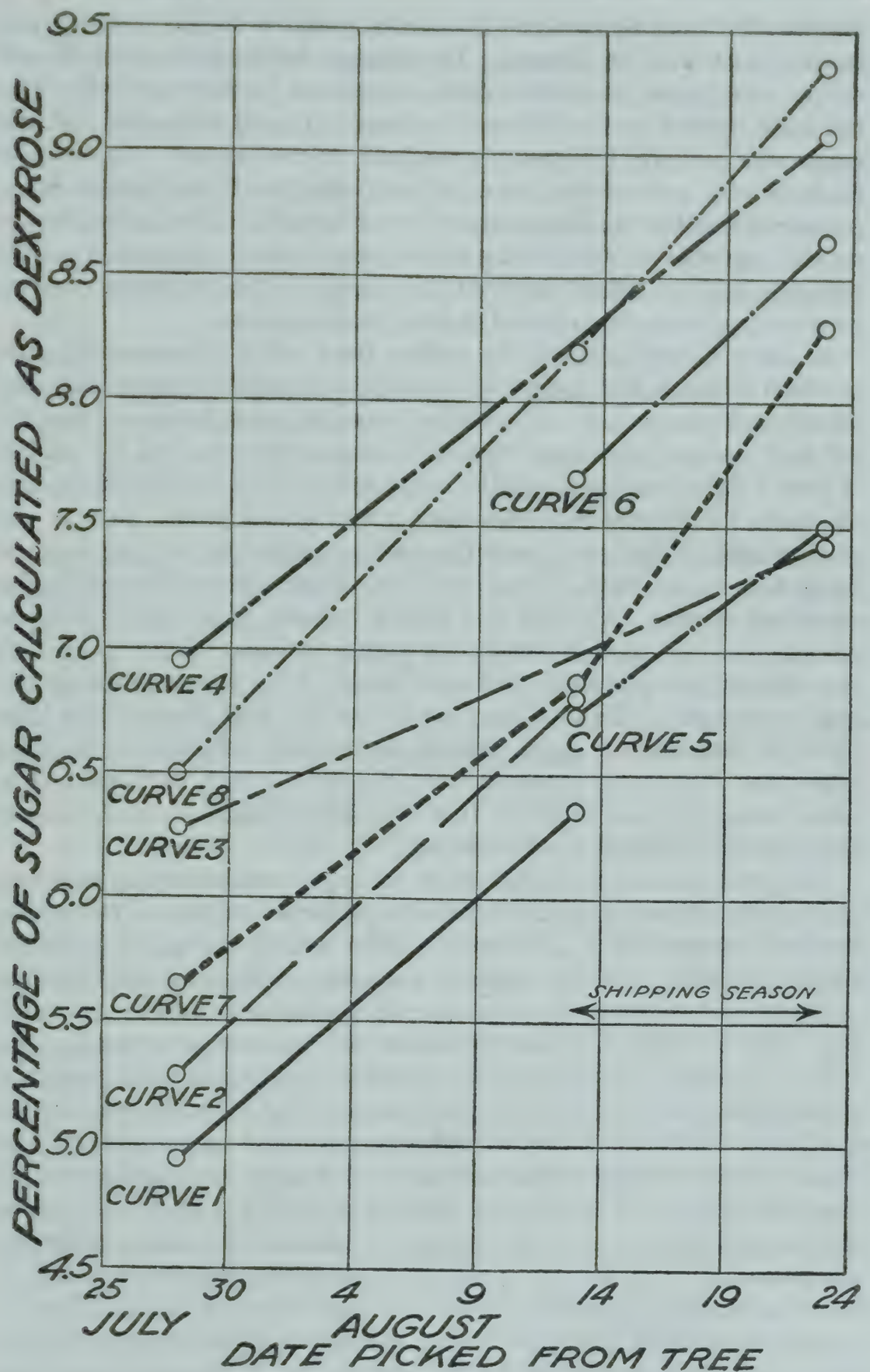

FIG. 4.—Sugars in Bartlett pears from Yakima, Wash.: Curve 1, reducing sugars in green fruit when picked from the tree; curve 2, total sugars in green fruit when picked from the tree; curve 3, reducing sugars in collateral lots after ripening at 70° F.; curve 4, total sugars in collateral lots after ripening at 70°; curve 5, reducing sugars in collateral lots after ripening at 40°; curve 6, total sugars in collateral lots after ripening at 40°; curve 7, reducing sugars in collateral lots after ripening at 30°; curve 8, total sugars in collateral lots after ripening at 30°.

temperature from 65° to 70° F., curves 5 and 6 in 40° storage, and curves 7 and 8 in 30° storage. The distance between these curves and curves 1 and 2, at the various dates, represents the increase in sugar as the fruit ripened in the different storages. It will be noted that the sugar runs uniformly highest in the fruit ripened at 70°. This is true for both total and reducing sugar in fruit picked at all the different dates. Apparently, either the loss of sugar from respiration is less, or more substances insoluble or nonreducing in the green fruit are changed to soluble reducing material when the fruit is ripened at this optimum ripening temperature than when ripened at lower temperatures.

In every lot, regardless of the section from which it came or the date at which it was picked, fruit held at 30° F. was higher in sugar than that stored until ripe at 40°. It must be borne in mind, however, that the 30° fruit was not completely ripened in storage but was held for periods of from a little over three months in the early picked lots to a little over six weeks for the last lots from Oregon and Washington. Then it was removed and held at warm room temperature until ripe, the time required being four to six days. This may have made some difference in the analytical results. Also, at one period, because of a sudden drop in temperature, the fruit picked in the earlier lots was partly frozen. It was thawed very gradually, and no ill effects of the freezing were noticeable afterwards. The fact that the frozen lots and those of the later pickings that did not freeze showed no marked difference in analyses other than that to be expected from the results with the same lots in other storages is also evidence that the carbohydrates of the fruit were not materially affected by the freezing.

The general effect of storage upon the sugar content of the fruit was very similar, however, in fruit from the different sections. The curves for total sugar—No. 2, 4, 6, and 7—cross in only one point in all the figures, showing that the relative amounts of sugar in the different storages run the same in all cases. It seems well established, therefore, that the highest amount of sugar will be secured by holding the fruit at optimum temperature for ripening. In case it is necessary to prolong the time of keeping the fruit, holding it at very low temperature until near the time it is needed and then ripening it up at optimum temperature gives a higher sugar content than holding it at a temperature just low enough to retard the ripening processes. From the results obtained by Gore (5) on the respiration activity of fruits at different temperatures, it would be expected that respiration would occur at least three times as rapidly in the 70° as in the 40° F. The number of days required to ripen the fruit in the two storages was about in the proportion of three days at 40° to one at 70°, so the total respiration activity would seem to be about equal. If this is true, it would seem that certain factors other than respiration must enter into the relative amounts of sugar present in the different storage lots.

RELATION OF SUCROSE TO REDUCING SUGAR DURING STORAGE

There is a marked increase in sucrose during the time between picking and the full ripening of the same fruit. This is shown by a comparison of the distance between curves 1 and 2, representing the sucrose in the fruit fresh from the tree, and between curves 3 and 4, showing the sucrose in the same fruit when ripe. There is a very marked increase in sucrose during storage in the earlier pickings, and this increase is even more marked in the late pickings. The late pickings show very little increase in reducing sugar between the time of picking and the time the fruit was ripened, while the increase in sucrose was very marked, being sufficient to make the total sugar increase between the time of picking and full ripeness practically as much in late-picked as in early picked fruit. There seems to be little relation between temperature and kind of sugar in the fruit, the 70°, 40°, and 30° F. storage lots being quite similar in the proportion of sucrose to reducing sugar.

A review of all the curves indicates that, whereas in the early picked fruit almost all of the sugar is in the form of reducing substances, the increase in reducing sugars in successive lots, as the season progresses, is much less marked than is the increase of sucrose. In all the lots, reducing sugar in the late picks seemed to run to between 7 and 8 per cent of the green weight of the fruit, after which there was very little increase in reducing substances, while sucrose continued to increase rapidly until after the last pickings were made.

RELATION OF ACIDITY TO TIME OF PICKING

In the relation of acidity to the time of picking there is not so distinct a correlation in all cases as there is for the sugars. Fruit from different districts seemed to respond somewhat differently in this regard, though certain general tendencies hold for all regions. Figures 5 to 8 summarize the results on acidity, computed as malic acid in terms of percentage of wet weight of the fruit. Curve 1 in each plot represents acid in the green fruit, curve 2 in fruit ripened at 70° F., curve 3 in fruit ripened at 40°, and curve 4 in fruit ripened at 30°.

In fruit from Suisun, Calif., (fig. 6) there is a constant decrease in acid in the green fruit from the time of the first picking until the last. On the other hand, in fruit from Sacramento (fig. 5) there is a slight rise until July 5, about the opening of the picking season, followed by a drop toward the end of the season. In fruit from the more northern sections, however, there is an increase in acid instead of a decrease. The increase is rather slight in the Medford pears (fig. 7), but very marked in those from Yakima (fig. 8). It is interesting to note that, whereas the acidity of the fruit decreased in the California sections, fruit from the Medford section showed a slight increase, and that from the still more northern Yakima section showed a very marked increase

as the season advanced. While the data are much too limited to justify the assumption that this relation of acidity to latitude generally holds, the results of the one year's work are of sufficient interest to warrant further study along this line.

EFFECT OF STORAGE UPON ACIDITY

A somewhat greater uniformity exists in the relation of temperature of storage to the acidity of the ripened product than was found in connection with the time of picking. In the first place, it will be noted

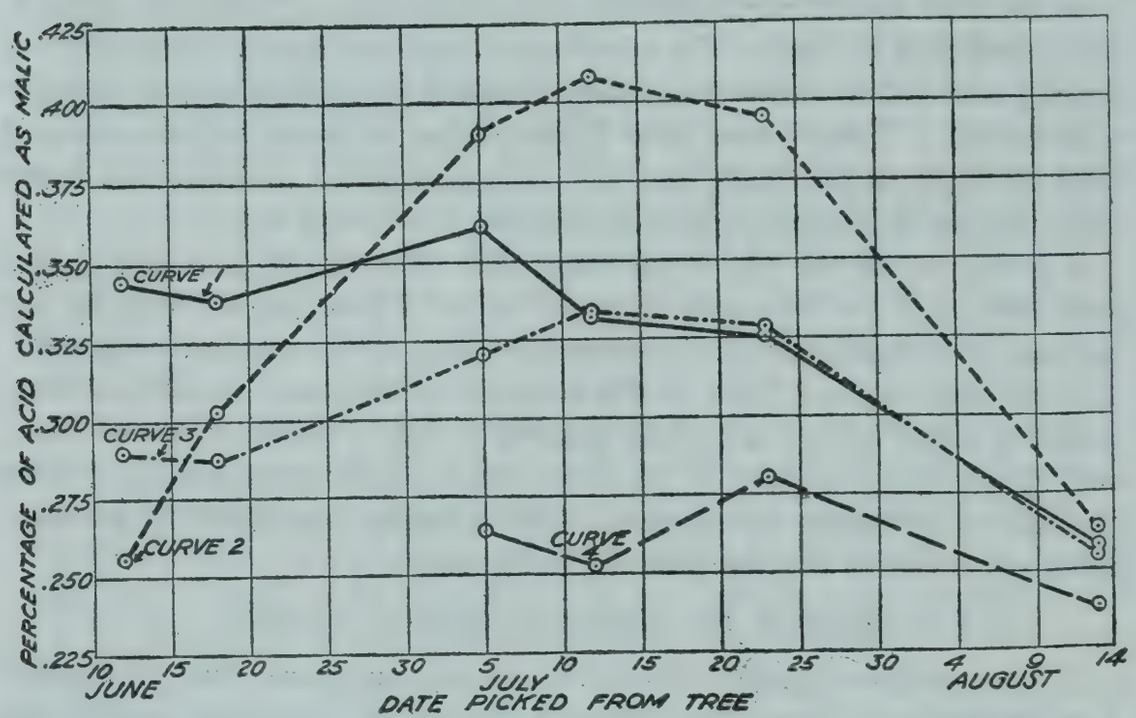

FIG. 5.—Acids in Bartlett pears from Sacramento, Calif.: Curve 1, acid in green fruit when picked from the tree; curve 2, acid in collateral lots after ripening at 70° F.; curve 3, acid in collateral lots after ripening at 40°; curve 4, acid in collateral lots after ripening at 30°.

that in the early picks there is a wide variation in amount of acid, due to the temperature of the storage used; and in most cases there is a greater amount of acid in the green fruit than in the ripened fruit, regardless of the temperature at which it was held. Fruit picked in a very immature condition has less acid when ripened than at the time of picking. (Curves 1–4, fig. 5–6, early pickings.)

Fruit picked at about the time of the opening of the commercial season, however, behaved somewhat differently. In every case the fruit ripened at 70° F. contained a higher percentage of titratable acid than did the same fruit when picked from the tree. This is of interest especially in connection with the question of whether fruit acids are synthesized in the fruit itself or whether they are carried to the fruit from the leaves. The fact that there is an increase in the acid between the time the fruit is removed from the tree and the time of its becoming ripe is evidence that there is an actual synthesis of acid in the fruit itself.

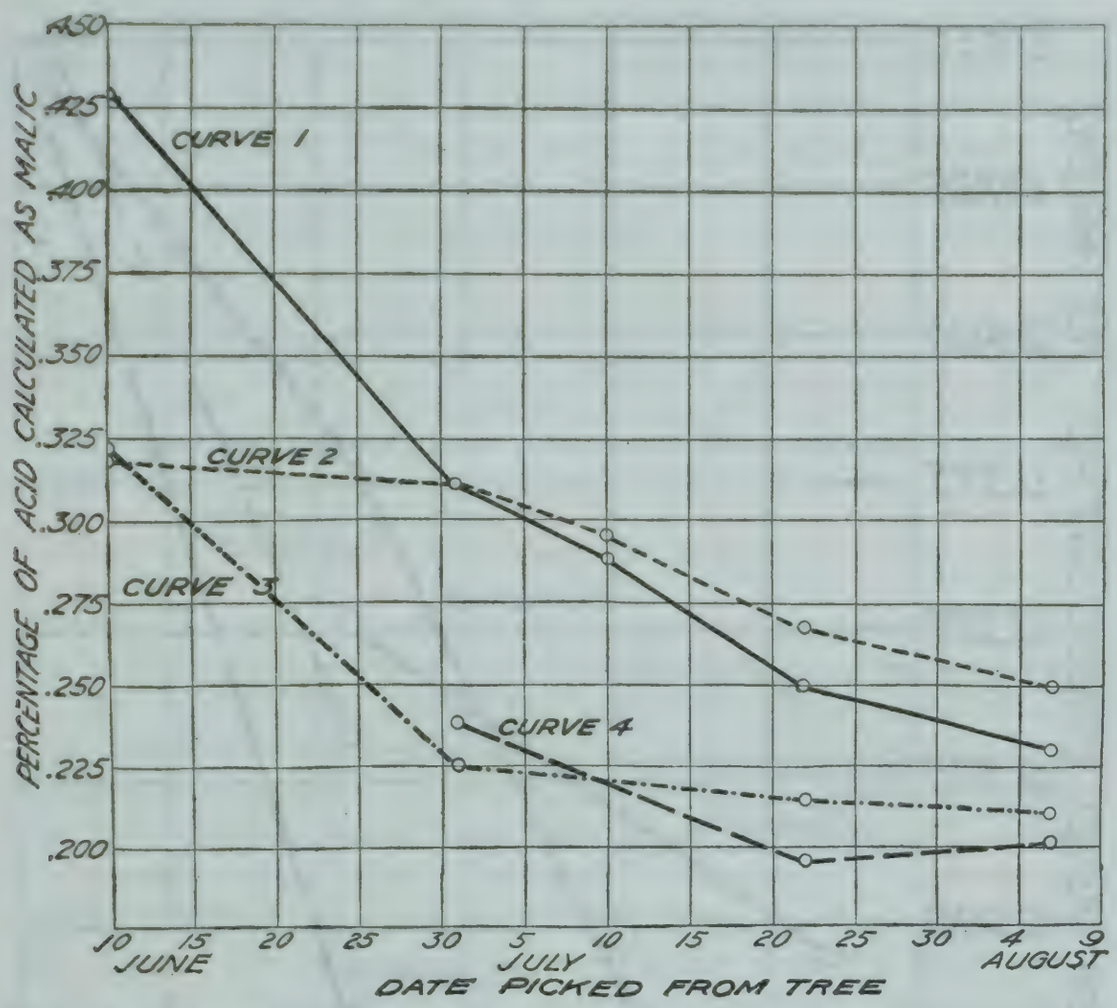

FIG. 6.—Acids in Bartlett pears from Suisun, Calif.: Curve 1, acid in green fruit when picked from the tree; curve 2, acid in collateral lots after ripening at 70° F.; curve 3, acid in collateral lots after ripening at 40°; curve 4, acid in collateral lots after ripening at 30°.

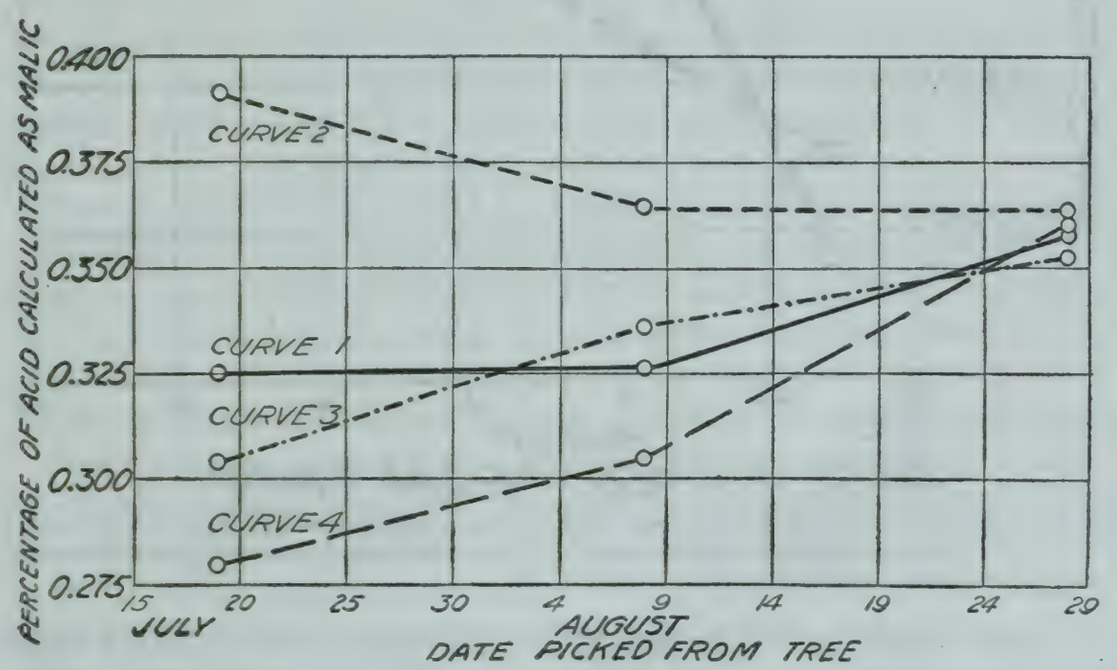

FIG. 7.—Acids in Bartlett pears from Medford, Oreg.: Curve 1, acid in green fruit when picked from the tree; curve 2, acid in collateral lots after ripening at 70° F.; curve 3, acid in collateral lots after ripening at 40°; curve 4, acid in collateral lots after ripening at 30°.

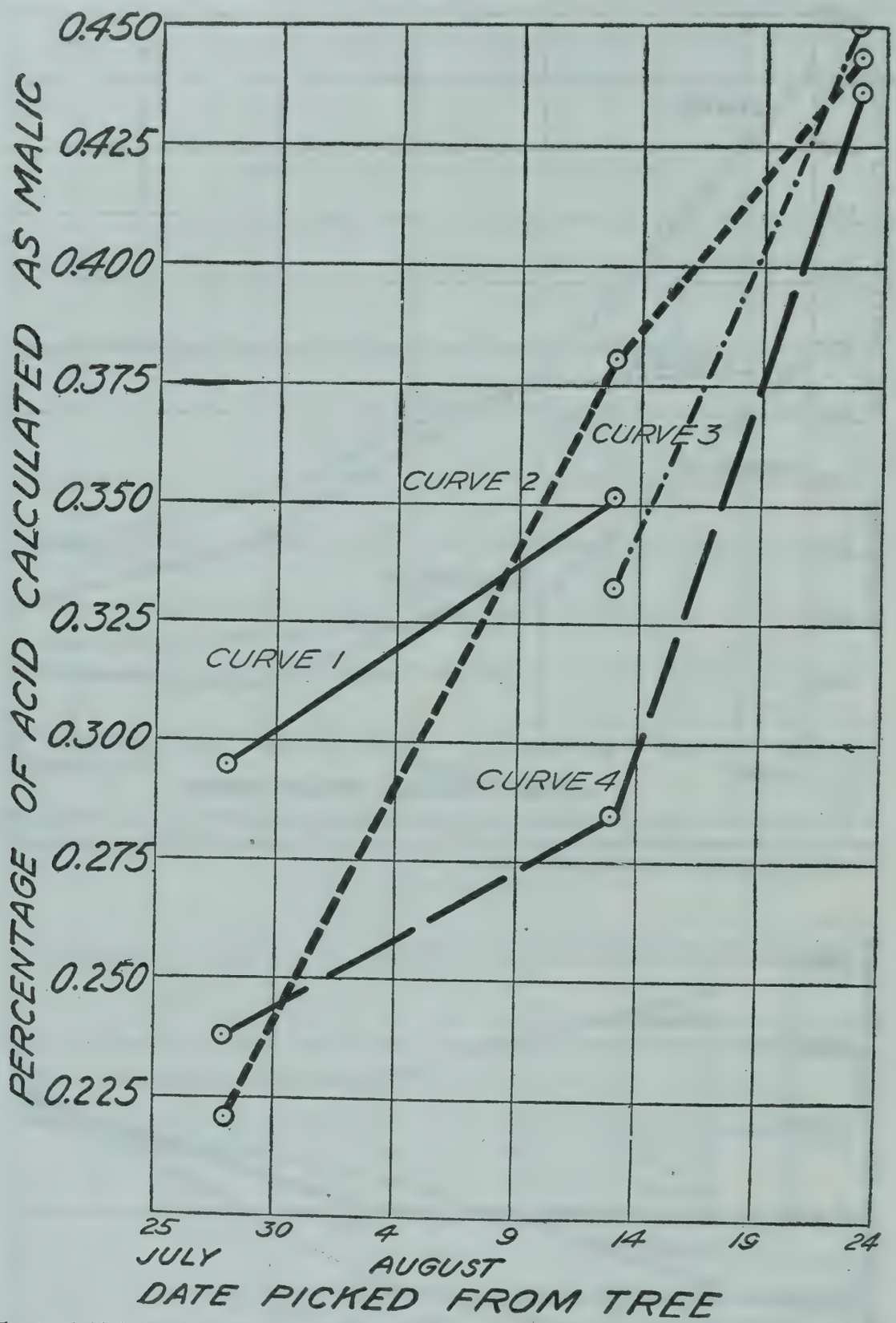

FIG. 8.—Acids in Bartlett pears from Yakima, Wash.: Curve 1, acid in green fruit when picked from the tree; curve 2, acid in collateral lots after ripening at 70° F.; curve 3, acid in collateral lots after ripening at 40°; curve 4, acid in collateral lots after ripening at 30°.

It was almost invariably true that fruit held at 30° F. had a lower acid content than that held in either 40° or 70° storage. This is especially interesting in connection with the fact that the sugars were much higher in the 30° storage lots than in the 40° pears. (Curves 2, 3, 4, fig. 5–8.)

In the latest picked lots from all sections the acid was very nearly the same, both in the green fruit and in the ripened fruit, regardless of the temperature of storage used. The acid content seems to become more nearly stabilized in the late season. It will be noted, however, that whereas the acid content in the California pears was very low at this time, in the fruit from the northern regions it was higher than at any other time during the season.

The question as to why the acid content should remain more nearly constant in late-picked than in early picked fruit is naturally suggested by these results, but until something more is known of the synthesis of the acids and the rôle they play in fruit and plant respiration a solution seems improbable.

ALCOHOL-INSOLUBLE, ACID-HYDROLYZABLE REDUCING SUBSTANCES

Results of analyses made as these were, by hydrolyzing the residue from an alcohol extraction with dilute acid and determining the reducing substances present, have usually been reported as starch. That this may be very misleading is shown by the fact that ripe pears contain no starch, as proved by iodin tests, yet the residue from the alcohol extraction after being hydrolized contained a considerable amount of reducing material. It is almost certain that an equal or even greater amount of such material found in the green fruit is also made up of substances other than starch. For this reason the percentage weight of this group of substances has been figured as dextrose, and the figure includes starch, together with certain hemicelluloses, galactans, pectin materials, etc., which may be present in varying amounts.

A study of the data presented in Tables I to IV shows that these reducing substances run highest in the earliest lots when first picked from the tree. There is a decreasing amount in the green fruit at successive pickings, until the last lots contain only about two-thirds as high a percentage of these substances as do the earliest pickings.

There is a very marked drop in the amount of alcohol-insoluble, acid-hydrolyzable reducing substances present in the storage-ripe fruit as compared to the similar lots when picked. Compare column 15, green, with columns 16 and 18, ripe. This, of course, is natural, since all the starch and probably some of the other material have disappeared. It is interesting to note, however, that there is also a decrease in the amount of these reducing substances in the ripe fruit from late pickings as compared to ripe fruit from early pickings. This decrease in many cases amounts to 50 per cent of the total and seems to indicate that as the fruit develops on the tree much material other than starch changes over to sugar or is in condition to change over after picking.

These results are interesting when considered in connection with the findings of Lewis, Murneek, and Cate (*9*) on the decreasing resistance of

the pear tissue to pressure as the season advances. The pectose material is generally thought to be largely responsible for the thickening and cementing together of the cell walls and hence for the firm texture of fruit. The association of the decrease in amount of this and related material with decreasing resistance of the tissue to pressure is evidence in support of this theory.

The temperature at which the fruit was stored has no marked influence on this material. A comparison of the lots picked at the same time and stored under the different temperature conditions (Tables I–IV, columns 16–18) shows little variation.

INFLUENCE OF TIME OF PICKING AND TEMPERATURE OF STORAGE UPON PERCENTAGE OF DRY WEIGHT

In this report, sugars and acids have been figured to percentage of the wet weight, as it is considered that wet weight rather than dry weight percentage will give the most accurate index of quality. The data for total dry matter in the fruit are of much importance, however, especially in connection with the pear dehydration industry, and for the purpose of throwing light upon the question of how much shrinkage, due to loss of moisture, occurs in the fruit during storage.

From the data on dry weights presented in Tables I to IV it will be noted that while considerable variation seems to occur in various individual lots, one or two things stand out as of special interest. In the California fruit, in which the first pickings were made much in advance of the commercial season and when the fruit was very immature, the percentage of dry weight was higher in the earliest lots than it was in those lots picked during the main commercial shipping season, a month later. (Tables I and II, columns 19–22.) Toward the end of the season, however, the percentage of dry matter increased until the last pickings gave the highest dry-weight figures of all lots. The first pickings of the Oregon and Washington fruit (Tables III and IV) were made at a somewhat later relative date than the first pickings from California, so the fact that the earliest pickings show a low dry weight is in accord with the data for California sections.

Thus it is at once apparent that, for purposes of dehydration, pears left on the tree as long as possible will give not only the greatest tonnage, because of the size of the fruit, but will also give the greatest weight of the dried product per pound of green weight. Consequently, it is of special importance that pears intended for drying be left on the trees as long as possible.

If the dry weight of the fruit at the time of picking is compared with the dry weight of the same lots when they come from storage fully ripe it is seen that for well-matured fruit there is very little moisture loss during storage. A comparison of the earliest lots from Suisun and from Sacramento (Tables I and II) is interesting in that the Sacramento fruit was wrapped, whereas that from Suisun was loose in the box and unwrapped. There is no increase in dry weight in the Sacramento fruit,

while the early lots from Suisun show a marked increase during storage. This indicates the value of wrapping in preventing loss of moisture from fruit.

Examination of somewhat later lots picked during the commercial season shows no increase in dry weight while the fruit is in storage, and in many cases it shows an actual decrease. All the storages used were comparatively high in humidity, otherwise there might have been a loss due to more rapid evaporation from the fruit.

An examination of the lenticels of the fruit of the different lots was made as the fruit was freshly picked. A number of pears were put in methylene blue solution and after soaking a short time were removed and the lenticels examined under a microscope. It was found that the methylene blue readily penetrated the lenticels of the immature, early picked fruit. Fruit picked at the opening of the commercial season, however, had a layer of brown, suberized tissue formed in the lenticel, which prevented the penetration of the blue solution. Later in the season pears immersed for a considerable length of time and then rinsed in water showed only a very faint blue ring about the outside of the lenticel. The corky layer had apparently almost completely stopped penetration of the solution. Even when an immersed pear was placed under reduced pressure for a time and then under full atmospheric pressure the solution did not penetrate the lenticels.

With practice, this condition of the lenticels can be detected by the brown color of the corky growth without the use of a microscope and dye solution. It appears that this change in the lenticels may be a valuable aid to present methods of determining when the fruit is in condition to pick and handle without danger of shriveling or wilting.

EFFECT OF TIME OF PICKING UPON LENGTH OF TIME FRUIT MAY BE STORED

Table V shows the number of days between the time the fruit was picked from the tree and the time of full yellow ripeness. The Yakima fruit is not included, since the number of days in transit and the fact that one lot was delayed en route makes an accurate comparison impossible.

TABLE V.—*Number of days required for fruit to become soft, yellow ripe at different temperatures of storage*

Sacramento, Calif.			Suisun, Calif.			Medford, Oreg.		
Date of picking.	Number of days at 70° F.	Number of days at 40° F.	Date of picking.	Number of days at 70° F.	Number of days at 40° F.	Date of picking.	Number of days at 70° F.	Number of days at 40° F.
June 12	14	48	June 10	15	49	July 19	13	31
18	14	45	July 1	15	41	Aug. 8	13	26
July 5	14	32	10	14	.....	28	11	23
12	14	33	22	13	32	.....	.....	.....
Aug. 13	12	24	Aug. 6	12	28	.....	.....	.....

The variations in the length of time required for the fruit from the different localities to become ripe in 40° F. storage may be due in part to the different lengths of time spent in transit to place of storage.

From this it is apparent that the results attained are similar to those found by other investigators—namely, that at the higher temperatures of storage, early picking gave somewhat longer keeping time than later picking. It has been impossible in this work to determine the relative keeping time at temperatures lower than 40° F. because of the necessity of removing the fruit from storage before it reached a full ripe condition.

At the 40° F. storage it was found, however, that the early fruits tended to scald and become brown rather than to ripen in good condition, while the later pickings ripened to full yellow and prime condition with practically no scald. Another very important observation was that although late-picked fruit tends to become yellow more quickly than early picked lots, it remains in firm, prime eating condition for a much longer period after becoming yellow than the fruit picked early.

GENERAL DISCUSSION OF RESULTS AS APPLIED TO COMMERCIAL HANDLING

The disposition of the commercial pear crop of the Pacific coast may be grouped under three divisions, which include practically the entire output—namely, (1) fresh shipment, for consumption as fresh fruit or for home canning; (2) commercial canning; and (3) drying or dehydration. The method of handling must, of necessity, be varied considerably, depending upon which of these methods of marketing is to be followed.

When pears are to be shipped fresh, certain factors other than those which determine the very highest quality of fruit must be considered. Fruit picked comparatively early in the season will remain sound somewhat longer, even at the lowest temperatures that it is possible to secure while the fruit is in transit, than will that picked too late; and this must always be an important consideration in determining the time to pick for fresh shipment. It must be remembered, however, that late-picked fruit is richer in sugar and of much higher dessert quality than fruit picked and shipped very early. Furthermore, while late-picked fruit, especially in the relatively high temperatures necessary in cars in transit, comes to prime eating condition in a shorter length of time, it remains in prime condition for a longer period, a consideration of much importance to the retail trade.

In the cannery and dehydrated fruit trades, it is possible to sacrifice something in keeping quality for a higher dessert quality product. Most of the fruit is utilized near the point of production. In the cannery industry the largest problem is to secure a good product and at the

same time to plan so that the tremendous tonnage that comes on within a short period is utilized before the fruit becomes overripe and breaks down. Almost every year canners lose a considerable quantity of pears because the fruit becomes overripe before the cannery can handle it.

The first consideration of the canner should be the securing of a high quality product by leaving the fruit on the trees until well developed. Pears picked very early are low in the natural fruit sugars and are of very inferior quality, whether eaten fresh or canned. A high-grade canned product can be secured only by using a high quality of fruit.

If this is done, it becomes practically necessary for the cannery man to store part of his season's supply. If certain conditions of storage are carried out, the keeping of Bartlett pears in storage, even up to two months, and still securing a high-quality product is a practical certainty. These conditions may be summarized briefly as follows:

(1) Use only well-developed fruit for storage. Early pickings tend to "scald" or turn brown and decay and break down much faster when removed from storage.

(2) Put fruit into storage immediately after it is picked. The maximum time that should elapse between picking and storing should not be more than three or four days. The cannery man will know the capacity of his plant; and, if more tons are being picked each day than he can handle, unless some go directly into storage, he can be sure that his cannery will be "flooded" when the fruit ripens. The fruit should go to the storage as soon as picked, rather than when it begins to soften. Much loss in pears in cold storage occurs because the fruit is in an almost soft-ripe condition when put in.

(3) Fruit should be cooled as quickly as possible after being placed in storage. It is especially desirable that a room with a large amount of direct expansion or brine piping be used, so that the temperature can be reduced quickly to 30° F. The fruit will cool somewhat more slowly than the air, although, if the fruit is loose in lug boxes, it will follow the air temperature rather closely.

(4) An even temperature should be maintained. If the storage rooms are large, it will be well worth while to use certain rooms for cooling down the fruit when it arrives, after which it may be transferred to other rooms for holding. This eliminates putting warm fruit into a room in which other fruit, already cooled, is being held. While this necessitates an extra handling, it is well worth while if it is desired to hold the fruit for some time. Especially is this system desirable if certain rooms having greater cooling capacity can be utilized for this precooling.

(5) The temperature should be held down to 28° or 30° F. if a long storage period is desired. Well-developed Bartlett pears will store at that temperature, ripen in excellent condition if removed at any time up to two or three months, and give a high-quality product. If it is desired

to hold the fruit for only a few weeks, somewhat higher temperatures are permissible; but even for short storage periods a low temperature, followed by the removal of the fruit and ripening at outside air temperature, gives a better product.

(6) The cooling capacity of the storage plant should not be overtaxed. It is possible in the case of Bartlett pears to "store on the tree" to a very marked extent. Two weeks' time on the tree makes only a small difference in the length of time pears will remain sound after removing from the tree, so for cannery trade it is not necessary to pick the entire crop within a very short time. Of course, other factors, such as amount of drop, load on the trees, etc., must be considered.

The foregoing suggestions presuppose a very close working agreement between producer, canner, and cold storage; and this is essential for successful handling of Bartlett pears through cold storage. The fruit must be sent to the storage plant quickly if it is to be held in storage, and the cooling capacity must be such that the fruit can be cooled down within a short time. The temperature and storage recommendations apply only to Bartlett pears, since other varieties have been found to give different responses under storage treatment (*8*, *9*).

For the dehydration of Bartlett pears, if a drying plant is used, the same principles apply as for canning. On the other hand, if sun drying is used, the problem is much simplified, as the fruit can be handled in almost any quantity within a short time. For drying, however, it is of twofold importance that the fruit remain on the trees as long as possible, for the quality is not only improved but the accumulation of sugars gives an increase in the weight of dried product per pound of green fruit.

SUMMARY

There is a marked and quite uniform increase in total sugar in Bartlett pears from early summer until after the time of the close of the commercial picking season. The increase during the latter part of the season is mainly due to an accumulation of sucrose, while the earlier increase is due mainly to reducing sugar.

A distinct relationship was found between the total amount of sugar present in the ripe fruit and the temperature of the storage at which it had been held from the time of removing from the tree until ripe. Pears ripened at 70° F. contained the highest percentage of sugar, those ripened at 40° possessed the lowest total sugar content, and those held at 30° for from 6 to 14 weeks and then ripened at room temperature were intermediate in amount of total sugar. There was no marked relation between temperature of storage and relative amount of sucrose and reducing sugar.

Percentage of titratable acid in the fruit tended to decrease in fruit from the California sections as the season advanced, while it tended to

increase in that from Oregon and Washington. There was an increase in acid between the time of picking and the time of full ripening of the fruit when held at 70° F. There was much less acid in fruit ripened at 40° than in that ripened at 70°, and still less in fruit that had been held at 30°. The acid content of the fruit that was allowed to become well matured on the tree remained nearly constant during storage,

There was a progressive reduction in the alcohol-insoluble, acid-hydrolyzable reducing material as the season advanced, not only in the fruit fresh picked from the tree, but also in the same fruit after ripening. There is a marked reduction in these substances between the time when the fruit is first picked and the time when the same fruit becomes ripe.

The percentage of total solids is lowest at about the opening of the commercial season. This tends to increase with the accumulation of sugar in the late-picked lots.

With proper precautions of picking, handling, and storing, Bartlett pears can be held two to three months in storage and then taken out in good condition.

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FURTHER DATA ON THE ORANGE-RUSTS OF RUBUS

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In 1916 the writer showed that there exists in the United States two orange-rusts on species of Rubus (*1*).[2] Morphologically these rusts closely resemble each other in their caeoma stages, but in the behavior of the orange spores when germinated and in life cycle they were shown to differ. During the last two seasons further observations were made on the orange-rusts, and it is the object of the present paper to report the results obtained in this study.

Atkinson (*2*) has performed some experiments which to him seemed to indicate that there is only one orange-rust on species of Rubus in the United States. He admits that the orange spores show two distinct methods of germination but attributes this to the influence of temperature. According to his view, promycelia are produced at high temperatures and germ tubes at low temperatures. He suggests that this may explain the behavior of the orange-rusts in different parts of the country. In the north and in mountainous regions where the spring temperatures are relatively low the aeciospores produce germ tubes, while in southern sections of the country where temperatures are high they produce promycelia.

The writer (*7*) has previously reported the behavior of the aeciospores of the two orange-rusts when germinated side by side at a room temperature of about 25° C. This experiment seemed to show conclusively that the aeciospores of the two rusts differ in manner of germination. Nevertheless, in view of Atkinson's results some further germination tests have been made.

GYMNOCONIA INTERSTITIALIS ON BLACK RASPBERRY

In the fall of 1916 the writer collected the telia of *Gymnoconia interstitialis* on leaves of wild black raspberry plants growing on the Virginia side of the Potomac River near Washington, D. C. These telia showed that the long-cycled rust is present in the locality just mentioned. Since that time many collections of orange-rust have been made from both wild and cultivated Rubus plants in the vicinity of the city of Washington. A study of these specimens has shown that the rust on the black raspberry is always long-cycled while the rust on the blackberry and

[1] The writer wishes to acknowledge here the help he has received from many colleagues who have offered suggestions or have sent him living specimens of the rusts.

[2] Reference is made by number (italic) to "Literature cited," p. 512.

dewberry plants, so far as has been observed, is short-cycled in this region. Wild blackberry and black raspberry plants occur abundantly along the Potomac River in both Maryland and Virginia. They are frequently intermingled with each other, and often both are infected with orange-rust. During the springs of 1917 and 1918 the two rusts were many times found growing close to each other, and during both seasons the telia of Gymnoconia were found occurring sparingly on leaves of wild black raspberry plants. The telia were always found on or near those plants that had borne caeomas of Gymnoconia. They were never found on any blackberry host. Many cultivated blackberry and black raspberry fields in the vicinity of Washington are troubled with orange-rust. In every instance the germination tests have shown that the raspberry plants are infected with the long-cycled rust. Rust found in the cultivated blackberry fields is always the short-cycled form.

Plate 92 shows the way the aeciospores of the two rusts germinate on Beyerinck agar at room temperature (about 25° C.). The spores shown in Plate 92, A, were taken from leaves of wild black raspberry at West Falls Church, Va. They have produced long germ tubes. Those shown in Plate 92, B, were collected at the same place on wild blackberry. They have produced promycelia-bearing sporidia.

INFLUENCE OF TEMPERATURE ON GERMINATION

In order to study the effect of temperature on germination numerous collections were made from both wild and cultivated blackberry and raspberry plants. The spores were germinated in Petri dishes on water and on Beyerinck agar. The cultures were incubated at temperatures varying by 5° intervals and ranging from 0° to 30° C. None of the spores of either rust germinated at 0°. At 5° excellent germination was obtained, but growth was slow. At all of the higher temperatures—10°, 15°, 20°, 25°, and 30°—the spores of the two rusts germinated equally well. It was noted that at low temperatures such as 5° and 10° the spores of the long-cycled rust began to germinate somewhat sooner than those of the short-cycled rust. Germination in cultures of both kinds of spores took place more rapidly at 30° than at any of the lower temperatures. Fewer spores germinated, however, at this temperature than at the lower temperatures. The spores of both rusts germinated well at all the temperatures tested between 0° and 30°.

Spores taken from blackberry leaves always produced promycelia, while those from the black raspberry leaves produced long germ tubes. Mature aeciospores of the two rusts collected at the same time and often within a few feet of each other and incubated at the same temperatures and on the same media always showed the same differences in manner of germination. The promycelia produced by the spores from blackberry leaves are typical in every way. They become divided into

four or more cells, and usually four of these contain one nucleus each. Each nucleated cell is capable of producing a sporidium. The germ tubes arising from spores borne on raspberry leaves are long and sinuous. By suitable methods of staining they have been shown to contain two nuclei. At an early stage in germination they may be distinguished from promycelia by their smaller diameter and more rapid longitudinal growth. Temperature, within the range tested, has no effect on the manner in which the aeciospores of these two rusts germinate. In the vicinity of Washington, D. C., at Mountain Lake, Va., and at French Creek, W. Va., both rusts occur side by side under the same conditions of temperature and climate. The writer is, therefore, unable to accept the theory that temperature determines whether spores of a given orange-rust specimen will produce germ tubes or promycelia.

COLOR OF SPORES IN MASS

The finding of the two orange-rusts growing within a short distance of the laboratories of the Bureau of Plant Industry made it easy for the writer to compare them more carefully than was possible when they had to be brought from different parts of the country. The comparison of the rusts as they occur side by side on their living hosts has brought to light certain differences that were not noticed earlier. One of the most important of these is the color of the spores in mass.

It soon became evident that the spores of the short-cycled rust are lighter in color than those of Gymnoconia. The spore colors of the two rusts were matched on Ridgeway's color chart. According to this chart the spores of the short-cycled rust are cadmium orange, while those of the long-cycled rust are xanthine yellow. These two colors do not differ greatly from each other and stand side by side in the chart. Nevertheless they can be easily distinguished after one has once noted the difference between them. It is surprising that this difference was not seen earlier, especially since account was taken of the color of the spores in mass. It seems that failure in this regard was due to the fact that the color of the spores of both rusts begins to fade within a few weeks after they are collected, and differences in shade of color were attributed to fading.

It was at first thought that the difference in color between the spores on raspberry and on blackberry leaves might be due to the difference in host. In order to test this hypothesis a number of collections were made during the spring of 1917 and 1918. The long-cycled rust was collected on both wild and cultivated black raspberry at French Creek, W. Va. It was collected on wild blackberry (identified as *Rubus alleghaniensis*) at Mountain Lake, Va. Numerous collections were made in the Adirondack Mountains near Old Forge, N. Y., and in the White Mountains near Glen and Jackson, N. H. It was also collected

on black raspberry at Rouses Point, N. Y. Collections of the short-cycled rust were made on wild dewberry and wild blackberry at French Creek, W. Va., on wild dewberry at Mountain Lake, Va., and on wild blackberry and dewberry plants at many other points.

The material collected in 1917 and 1918 was brought together for comparison at the end of each season and before there was serious fading in the color of the spores. This comparison has shown that for the material at hand the two orange-rusts exhibit the same color differences regardless of the hosts on which they occur or the localities from which they are collected. The color difference makes it possible to identify the two rusts in the field without resort to spore germination.

Plate D illustrates the difference in the color of the spores in mass. Figure 1 shows an infected black raspberry leaf, figure 2 an infected blackberry leaf.

MORPHOLOGY OF AECIOSPORES

In a former paper the writer (7) has pointed out that no morphological differences could be observed between the aeciospores of certain specimens of the two orange-rusts. While this statement was true for the specimens under study, it does not hold when larger numbers of specimens of the two rusts are compared. A study of more than 100 different collections has shown that the spores of the two rusts differ considerably from each other both in size and in shape. While a few specimens may not reveal this fact, a more extended study shows that the aeciospores of the two rusts are, on the whole, morphologically different.

In order to show this difference more clearly than is possible by description, an outline drawing has been made of a few typical aeciospores from a number of different specimens of the two rusts. The drawings were made with the aid of a camera lucida. The same magnification was used for all spores, so that the different drawings may be readily compared. There is always a certain amount of variation in the size and shape of the spores of a given specimen. This is greater for some specimens than for others, and it was not always easy to select spores that would be typical. Before material for drawing was chosen, spores from several mature caeomas on each specimen were transferred to separate drops of water on glass slides. They were then observed under the microscope, and a group was finally chosen that seemed to be typical for the specimen in question. Table I gives information regarding the place and time of collection, host, manner of germination, and color of spores in mass for most of the specimens collected in 1917 and 1918. Numbers given in the last column of the table indicate the drawings in Plates 93 and 94, which show an average sample of spores for each specimen.

TABLE I.—*Place and time of collection, host, manner of germination, and color of the aeciospores in mass for most of the specimens collected in 1917 and 1918*

Place of collection.	Time of collection.	Host.	Manner of germination.	Color of spores in mass.	Plate No.
Falmouth, Mass.	June 20, 1918	Wild dewberry	Promycelia	Cadmium orange.	93, fig. 1
Arlington, Va.	June, 1918	Wild blackberry	do	do	93, fig. 2
Massachusetts	June 27, 1917	do	do	do	93, fig. 3
Berlin, Md.	June 8, 1917	Cultivated blackberry	do	do	93, fig. 4
Hyattsville, Md.	June 15, 1918	Wild dewberry	do	do	93, fig. 5
West Falls Church, Va.	May 21, 1918	do	do	do	93, fig. 6
Auburn, Ala.	Apr. 27, 1918	do	do	do	93, fig. 7
Fayetteville, Ark.	June 7, 1917	Wild blackberry	do	do	93, fig. 8
Potomac Heights, D. C.	June, 1917	do	do	do	93, fig. 9
Morgantown, W. Va.	June 7, 1918	Cultivated blackberry, variety Eldorado.	do	do	93, fig. 10
Blacksburg, Va.	June 11, 1918	Cultivated blackberry, variety Iceberg.	do	do	93, fig. 11
Ithaca, N. Y.	June 4, 1918	Wild blackberry	do	do	93, fig. 12
Blacksburg, Va.	May 25, 1917	do	do	do	93, fig. 13
West Falls Church, Va.	May 21, 1918	do	do	do	93, fig. 14
Gainesville, Fla.	Mar. 25, 1918	*Rubus cuneifolius*	do	do	93, fig. 15
Ithaca, N. Y.	June, 1918	Wild blackberry	do	do	93, fig. 16
Chico, Calif.	May 1, 1918	*R. ursinus*	do	do	93, fig. 17
Ithaca, N. Y.	June 4, 1918	Wild dewberry	do	do	93, fig. 18
Arlington, Va.	June, 1918	Wild blackberry	do	do	93, fig. 19
Berkeley, Calif.	Mar. 30, 1918	*R. parviflorus*	do	do	93, fig. 20
Hammonton, N. J.	June 20, 1918	Cultivated blackberry	do	do	93, fig. 21
Fayetteville, Ark.	June 7, 1917	Wild blackberry	do	do	93, fig. 22
West Falls Church, Va.	May 21, 1918	do	do	do	93, fig. 23
French Creek, W. Va.	June 8, 1918	Wild dewberry	do	do	93, fig. 24
Congress Heights, D. C.	May 20, 1918	Wild blackberry	do	do	93, fig. 25
Connellsville, Pa.	June 6, 1918	do	do	do	93, fig. 26
Chico, Calif.	May 19, 1918	*R. ursinus*	do	do	93, fig. 27
Vienna, Va.	May 21, 1918	Wild blackberry	do	do	93, fig. 28
Bryan, Ohio	June 12, 1918	Cultivated blackberry.	Germination very poor.	Color faded	93, fig. 29
Cameron, N. C.	June 4, 1918	Wild blackberry	Promycelia	Cadmium orange.	93, fig. 30
Athens, Ohio	June 11, 1918	do	do	do	93, fig. 31
Blacksburg, Va.	do	Cultivated blackberry, variety Early King.	do	do	93, fig. 32
Chico, Calif.	May 1, 1918	*R. ursinus*	do	do	93, fig. 33
Arlington, Va.	June, 1918	Wild blackberry	do	do	93, fig. 34
Ithaca, N. Y.	do	Wild dewberry	do	do	93, fig. 35
Mountain Lake, Va.	June 11, 1918	*R. americanus*	do	do	93, fig. 36
French Creek, W. Va.	June 8, 1918	Wild dewberry	do	do	93, fig. 37
Blacksburg, Va.	June 11, 1918	Cultivated blackberry.	do	do	93, fig. 38
Do.	do	Cultivated blackberry, variety Mersereau.	do	do	93, fig. 39
Vienna, Va.	do	Cultivated blackberry.	do	do	93, fig. 40
Ithaca, N. Y.	June 4, 1918	Wild blackberry	do	do	93, fig. 41
Blacksburg, Va.	June 11, 1918	Cultivated blackberry, variety Ancient Britain.	do	do	93, fig. 42
Janassee Junction, Ga.	May 14, 1918	Wild blackberry	do	do	93, fig. 43
Thunderbolt, Ga.	Mar. 17, 1918	*R. procumbens*	do	do	93, fig. 44
Hyattsville, Md.	June 15, 1918	Wild dewberry	do	do	93, fig. 45
Do.	do	Wild blackberry	do	do	93, fig. 46
Blacksburg, Va.	June 11, 1918	Cultivated blackberry.	do	do	93, fig. 47
Vienna, Va.	May 29, 1918	Wild blackberry	do	do	93, fig. 48
Willard, N. C.	June 26, 1917	do	do	do	93, fig. 49
Connellsville, Pa.	June 8, 1918	do	do	do	93, fig. 50
Auburn, Ala.	Mar. 4, 1918	do	do	do	93, fig. 51
Butte Creek Canyon, Calif.	May 19, 1918	*R. ursinus*	do	do	93, fig. 52
Stark, Fla.	1917	Wild blackberry	do	do	93, fig. 53
Blacksburg, Va.	June 11, 1918	do	do	do	93, fig. 54
Thunderbolt, Ga.	Mar. 17, 1918	*R. hispidus*	do	do	93, fig. 55
Hyattsville, Md.	June 15, 1918	Wild blackberry	do	do	93, fig. 56
Blacksburg, Va.	May 25, 1917	do	do	do	93, fig. 57
Hammond, La.	Mar. 29, 1918	do	do	do	93, fig. 58
Orlando, W. Va.	June 8, 1918	do	do	do	93, fig. 59
Ithaca, N. Y.	June 4, 1918	do	do	do	93, fig. 60
Blacksburg, Va.	June 12, 1918	do	do	do	93, fig. 61
West Falls Church, Va.	May 21, 1918	Cultivated blackberry.	do	do	93, fig. 62
Arlington, Va.	June, 1918	Wild blackberry	do	do	93, fig. 63
Do.	do	do	do	do	93, fig. 64
French Creek, W. Va.	June 8, 1918	do	do	do	93, fig. 65
Madrid, Me.	July 3, 1917	do	Germ tubes.	Xanthine yellow.	94, fig. 1
French Creek, W. Va.	June 8, 1918	Black raspberry	do	do	94, fig. 2
Glen, N. H.	June 22, 1917	*R. nigrobaccus*	do	do	94, fig. 3

TABLE I.—*Place and time of collection, host, manner of germination, and color of the aeciospores in mass for most of the specimens collected in 1917 and 1918*—Continued

Place of collection.	Time of collection.	Host.	Manner of germination.	Color of spores in mass.	Plate No.
West Falls Church, Va.	May 21, 1918	Cultivated raspberry..	Germ tubes..	Xanthine yellow.	94, fig. 4
Vienna, Va.....	.....do.....	.....do.....	.....do.....	.....do.....	94, fig. 5
Old Forge, N. Y.....	June 27, 1918	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 6
Glen, N. H.....	June 22, 1918	Wild blackberry.....	.....do.....	.....do.....	94, fig. 7
Mountain Lake, Va..	June 11, 1918	*R. alleghainensis*	.....do.....	.....do.....	94, fig. 8
West Falls Church, Va.	May 21, 1918	Cultivated black raspberry.	.....do.....	.....do.....	94, fig. 9
Portland, Me.....	June 24, 1917	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 10
Madison, Wis.....	June 4, 1918	Wild blackberry.....	.....do.....	.....do.....	94, fig. 11
Phillips, Me.....	July 3, 1917	.....do.....	.....do.....	.....do.....	94, fig. 12
Portland, Me.....	June 24, 1917	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 13
East Lansing, Mich...	June 30, 1917	Wild blackberry.....	.....do.....	.....do.....	94, fig. 14
Sebago Lake, Me.....	June 23, 1917	*R. triflorus*.....	.....do.....	.....do.....	94, fig. 15
Michigan.....	June, 1917	Wild blackberry.....	.....do.....	.....do.....	94, fig. 16
Old Forge, N. Y.....	June 26, 1918	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 17
Madison, Wis.....	July 17, 1917	Wild blackberry.....	.....do.....	.....do.....	94, fig. 18
Old Forge, N. Y.....	June 27, 1918	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 19
West Falls Church, Va.	May 21, 1918	Wild black raspberry.	.....do.....	.....do.....	94, fig. 20
Do.....	July 4, 1917	Cultivated black raspberry.	.....do.....	.....do.....	94, fig. 21
Do.....	May 21, 1918	.....do.....	.....do.....	.....do.....	94, fig. 22
Glen, N. H.....	June 22, 1917	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 23
Mountain Lake, Va..	June 11, 1918	*R. alleghaniensis*.....	.....do.....	.....do.....	94, fig. 24
French Creek, W. Va.	June 8, 1918	Black raspberry.....	.....do.....	.....do.....	94, fig. 25
Portland, Me.....	June 24, 1917	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 26
Smugglers Notch, Vt.	July 11, 1917	*R. strigosus*.....	.....do.....	.....do.....	94, fig. 27
Madrid, Me.....	July 3, 1917	Wild blackberry.....	.....do.....	.....do.....	94, fig. 28
Old Forge, N. Y.....	June 27, 1918	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 29
Smugglers Notch, Vt.	July 11, 1917	.....do.....	.....do.....	.....do.....	94, fig. 30
Bancroft, Wis.....	July, 1917	*R. hispidus*.....	.....do.....	.....do.....	94, fig. 31
Julet, N. Y.....	June 26, 1918	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 32
French Creek, W. Va.	June 6, 1917	Black raspberry.....	.....do.....	.....do.....	94, fig. 33
Old Forge, N. Y.....	June 26, 1918	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 34
Madison, Wis.....	June 4, 1918	Wild blackberry.....	.....do.....	.....do.....	94, fig. 35
Portland, Me.....	June 24, 1917	*R. triflorus*.....	.....do.....	.....do.....	94, fig. 36
Sebago, Lake, Me.....	June 23, 1917	.....do.....	.....do.....	.....do.....	94, fig. 37
Smugglers Notch, Vt.	July 11, 1917	*R. canadensis*.....	.....do.....	.....do.....	94, fig. 38
Sebago Lake, Me.....	June 23, 1917	*R. triflorus*.....	.....do.....	.....do.....	94, fig. 39
Rouses Point, N. Y...	June 29, 1918	Black raspberry.....	.....do.....	.....do.....	94, fig. 40
Sebago Lake, Me.....	June 23, 1917	Wild blackberry.....	.....do.....	.....do.....	94, fig. 41
Mountain Lake, Va..	June 11, 1918	*R. alleghaniensis*.....	.....do.....	.....do.....	94, fig. 42
Bound Brook, N. J...	June 17, 1918	Black raspberry.....	No germination.	.....do.....	94, fig. 43
Glen, N. H.....	June 22, 1916	*R. canadensis*.....	Germ tubes..	Color faded.....	94, fig. 44

Plate 93 shows spores from 65 different specimens of the short-cycled orange-rust. Figures 1 to 44 on Plate 94 show spores from 44 different specimens of the long-cycled rust. The figures on these plates demonstrate that, on the whole, the aeciospores of the two rusts are morphologically different. The spores of the short-cycled rust are smaller than those of the long-cycled. They are also more angular and more elongated. Their shape is more irregular. It will be seen that the size and shape of the aeciospores from different specimens of the two rusts vary considerably. On this account it is not always possible by observing spores under the microscope to determine with certainty to which group a given specimen may belong. On the other hand, spore characters do make possible a rather accurate separation of specimens belonging to the two rusts. It is difficult to say just how accurate such determinations will be. Much depends on the specimens at hand and on the judgment of the one who undertakes such a task. The writer's determinations by this means have proved to be correct in about 85

per cent of the specimens studied. By this method it is possible to identify with a fair degree of accuracy orange-rust specimens in herbaria long after the spores are dead and have lost their color. It must be remembered, however, that it is always necessary to have a liberal quantity of mature spores in order to make determinations of value.

The figures on Plate 93 show the variation in the size and shape of spores from different collections of the short-cycled rust. The spores shown in most of the figures are relatively small and angular. Those shown in figures 9, 13, 39, 45, and 55 are large and round. They look like the spores of the long-cycled rust, but their color and manner of germination prove that they belong to the short-cycled rust. Figures 3, 10, 28, 29, 33, 35, 36, 44, and 57 show spores that resemble somewhat those of the long-cycled rust. The specimens from which these aeciospores were taken can not be satisfactorily identified on the basis of spore characters. The spores shown in all of the other figures on Plate 93 are characteristic for the short-cycled rust; but even in such cases one can not be absolutely sure that they belong to this fungus, for occasionally a specimen of the long-cycled rust bears spores like those shown in figure 35 of Plate 94. The aeciospores shown in this figure are small and angular; they do not look like spores of the long-cycled rust. Spores shown in figures 4, 6, 8, 9, 19, 25, 42, and 43 of Plate 94 resemble to a certain degree spores of the short-cycled rust. On the whole, however, aeciospores from different samples of the long-cycled rust are more uniform as regards size and shape than are those of the short-cycled rust.

GENETIC RELATIONSHIP BETWEEN THE TWO ORANGE-RUSTS

Although the two orange-rusts differ from each other in several characters, it must not be denied that they are alike in many respects. They are both systemic on species of Rubus. Their caeomas look much alike, and in many specimens the aeciospores are quite similar. These points of resemblance suggest a genetic relationship. Along with the further evidence that the two rusts are distinct and different from each other have come certain facts that strengthen this suggestion. In an earlier paper the writer mentioned finding a promycelium in a culture of aeciospores of the long-cycled rust. It was thought at the time that the spore producing the promycelium might have entered as a contamination. During the spring of 1917 and 1918 aeciospores of Gymnoconia collected in different parts of the country were germinated in great numbers. Each culture was carefully examined under the microscope. In many cultures only germ tubes could be found. A few promycelial germinations have been obtained, however, from spores of every collection of Gymnoconia which the writer made during the last two seasons. Sometimes such germinations are exceedingly rare,

but if enough spores are germinated the promycelia will be found. The spores of some collections produce them more often than those of other collections. In general it may be said that promycelia are produced more abundantly by aeciospores collected late in the season. They are not entirely absent, however, from cultures made with spores collected early in the season. The possibility of these promycelia being produced by spores of the short-cycled rust that have contaminated the cultures has been excluded in most instances. In order to do this, the aeciospores were taken from caeomas that had not yet opened. Moreover, many of the spores were collected and germinated in parts of the country where the short-cycled rust is not known to occur. If the promycelia appeared only in cultures from aeciospores collected in the South where the short-cycled rust is abundant, mixed infection might offer a possible explanation. But since they also occur in cultures of spores collected in the North where the short-cycled rust has never been found, this explanation is unsatisfactory. In the vicinity of Glen, N. H., orange-rust has been collected each spring since 1913. Spores taken from a number of different places in this vicinity have been germinated, but the short-cycled rust has not been found. In both 1917 and 1918, cultures made at Glen were studied and found to contain a few promycelia. Promycelia have also been observed in cultures of the aeciospores of the long-cycled rust collected at Old Forge, N. Y., where several seasons' search has failed to reveal the presence of the short-cycled rust. They have been found in cultures of aeciospores taken from the black raspberry at Rouses Point, N. Y., French Creek, W. Va., and at points in the vicinity of Washington, D. C. Promycelia were also found in cultures of aeciospores collected at Mountain Lake, Va., on *Rubus alleghaniensis*.

When spores of the short-cycled rust are incubated at room temperature (about 25° C.) on a favorable medium, they produce promycelia-bearing sporidia within 24 hours. Spores of the long-cycled rust placed under similar conditions produce long germ tubes within 24 hours. Promycelia have seldom been found in these cultures after so short a time. They occur in cultures of Gymnoconia only after a rather long period of incubation. They can usually be found after 3 or 4 days. In order to study the production of promycelia by the aeciospores of Gymnoconia, it is best to incubate cultures at a fairly low temperature. Temperatures varying from 10° to 15° are favorable. Promycelia are always slow to make their appearance in cultures of this rust. If incubation temperatures are high, many germ tubes die before they have time to develop into promycelia. Moreover, cultures kept at high temperatures are usually overgrown by saprophytic mold fungi and bacteria after a few days. Low temperatures check the growth of these organisms. Promycelia can be found most easily in

cultures of aeciospores kept at about 10° for a week or longer. It must be understood, however, that they are not produced very abundantly even under favorable conditions. Sometimes 1,000 germinated spores may be observed without the finding of a single promycelium, but usually several promycelia will be found for each 1,000 spores observed if the cultures are more than 4 days old. In some cultures they occur more abundantly.

It is interesting to note that most of the promycelia developing in cultures of the aeciospores of the long-cycled rust are abnormal, though normal ones are also present. Many of the abnormal promycelia produce one or more normal sporidia, and there can be no doubt regarding their true nature. The abnormal promycelia and their tardy appearance in the cultures seem to the writer to suggest that nuclear fusions and the subsequent reduction divisions are steps accomplished with difficulty in these spores. It would be highly interesting to study these phenomena cytologically, but the relatively small number of promycelial germinations makes such a task rather difficult.

From a study of many abnormal promycelia the writer has come to recognize certain structures as indicating an attempt at the production of sporidia. Some of these are cross walls, branches, especially those having a diameter less than that of the germ tube, and sporidia-like processes borne on structures that show more or less resemblance to sterigmata. In cultures of the aeciospores of the long-cycled orange-rust it is possible to find all gradations between normal promycelia and germ tubes that can hardly be recognized as promycelia at all. In order to show some of the stages between these two extremes a few drawings have been made of abnormal promycelia.

Figure 53 of Plate 94 shows a tube with two rather typical sporidia borne on typical sterigmata. No cross walls occur in this tube. Figure 49 shows a branched germ tube. A cross wall occurs just below the branch. No sporidia are borne on this tube, but there can be little doubt that this is an attempt at promycelium production. Figure 51 shows a germ tube with one cross wall and forked branches. One of these branches has produced a rather long club-shaped tube, while the other has developed into a sterigma-like process bearing a typical sporidium. A tube with one cross wall and several branches of small diameter is shown in figure 50. One of these branches is pointed like a sterigma and bears a spore that resembles a sporidium. Figure 45 represents a tube having one cross wall and several short branches. One of these branches is considerably enlarged toward its distal end and presents curves that suggest those of the normal sporidium. A short tube is shown in figure 47. This tube has one short branch which bears a sporelike body having curves that closely resemble those of a sporidium. The curves of the upper end of this body are especially like those of the

upper part of normal sporidia. Another short tube is shown in figure 46. This bears a branch with an enlarged end resembling a sporidium. A constriction at the point of the first bend in the branch would give rise to a fairly normal sporidium. Figure 48 shows a similar branch, but this time it arises from a very long germ tube. An unbranched tube is shown in figure 54. The diameter of the distal end of this tube is much less than that of the average diameter of germ tubes. Such a decrease in diameter frequently accompanies cross-wall production, branching, and other indications of an attempt at the production of sporidia. Figure 52 shows a tube with a branch of small diameter and one cross wall. The end cell has broken away from the remainder of the tube.

It must not be supposed that abnormal promycelia are uncommon in cultures of the short-cycled orange-rust or in cultures of germinating teliospores in general. Abnormal promycelia much like those described above have occasionally been found in cultures of the short-cycled rust. They are not common, however, under ordinary conditions of germination. In cultures of the aeciospores of Gymnoconia, on the other hand, most of the promycelia produced are abnormal.

The production of promycelia by the aeciospores of *Gymnoconia interstitialis* seems to the writer to be strong evidence that a close genetic relationship exists between the two orange-rusts. One of them is a typical short-cycled rust. It produces three kinds of spores: Spermatia, aeciospores, and sporidia. So far as the writer has observed it possesses one and only one life cycle. There is nothing unusual about this rust. The other orange-rust is long-cycled, but it is not a typical long-cycled rust. It is unusual in that it possesses two life cycles. In addition to the long cycle there is a much repressed short cycle, as shown by the occasional production of promycelia. We know that the germ tubes produced by these spores reinfect Rubus leaves. It is not known whether the sporidia can cause infection. Some of the sporidia have been seen to germinate. They appear normal in every way, and there seems to be no reason why they should not function.

So far as the writer knows no one has yet observed the production of promycelia in cultures of the European orange-rust of Rubus. Both Fischer (*4*) and Lindfors (*8*) have recently studied the manner of germination of the spores of this rust and have observed only germ tubes. Fischer, however, has shown a branch of small diameter coming from the end of one of his germ tubes. This suggests an attempt at promycelium production and leads the writer to believe that if large numbers of aeciospores of the European orange-rust are germinated and carefully observed promycelia will be found.

The findings of an occasional promycelium in cultures of the aeciospores of *Gymnoconia interstitialis* at once raised the question as to whether or not such a performance is usual among the rusts. It is not possible to

get much information on the question from the literature on the germination of rust spores. Most workers have not germinated aeciospores in large numbers, and a few promycelia in their cultures might easily have been overlooked. In order to settle this point it would be necessary to germinate the aeciospores of many different rusts in large numbers, and the writer has not undertaken this task. Nevertheless, it has seemed desirable to make a thorough study of the aeciospore germination of some other rust. For this study the aeciospores of *Aecidium fraxini* were chosen. These aeciospores are produced in large numbers and germinate readily on both water and Beyerinck agar. *A. fraxini* was found in abundance on black ash trees growing along the shore of Lake Champlain near Rouses Point, N. Y. Many cultures were made with aeciospores of this rust. The germinations were carefully observed, but not a single promycelium was ever found. Long, wavy germ tubes were produced. No cross walls or branches were observed. These spores produce germ tubes only.

Promycelia in cultures of the aeciospores of *Gymnoconia interstitialis* indicate that the two nuclei which ordinarily pass out into the germ tube and remain apart through many nuclear and cell divisions occasionally fuse in the spore or perhaps in the young germ tube. If we assume that reduction in chromosome number occurs here as in other promycelia and that the sporidia produced are capable of reinfecting the host, then *G. interstitialis* has a double life cycle such as has not been demonstrated for any other rust.

It is not believed that promycelia are commonly produced even in small numbers by the aeciospores of most rusts. On the other hand, it seems probable that other rusts will be found that possess double life cycles. Eriksson (*3*) has reported that the aecia of *Aecidium graveolens* which occur on species of Berberis are able to reproduce themselves, although they may also infect *Avena elatior* and give rise to *Puccinia arrhenatheri*. This strange behavior, which has never been accounted for, may be due to the production of promycelia by a certain number of the aeciospores. Recently Klebahn (*5*) reports that the aecia of *Peridermium pini* reproduce themselves on the pine. He states that the aeciospores give germ tubes, but a further study may show that some of them produce promycelia.

In an earlier paper (*6*) the writer expressed the opinion that the short-cycled orange-rust is more primitive than the long-cycled one. The fact that the long-cycled rust has a double life cycle is further evidence in favor of this view.

Arthur (*1*) considers the differences between the two orange-rusts sufficient to place them in separate genera. Moreover, these genera are widely separated in his classification. It would seem that the evidence of a genetic relationship between these rusts should be given consideration in any natural system of classification.

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A. Hoen & Co. Baltimore.

PLATE D

1.—Infected black raspberry leaf covered with the caeomas of *Gymnoconia interstitialis*. The spores in mass are xanthine yellow.

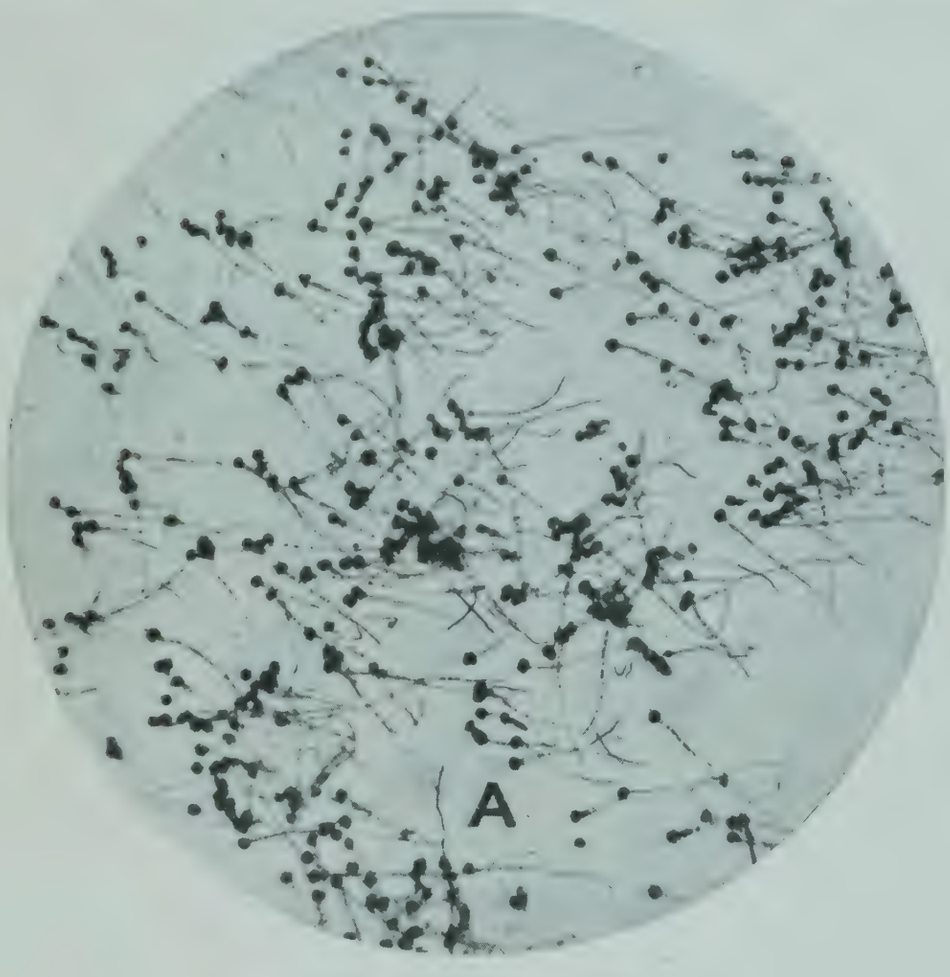
2.—Blackberry leaf infected with the short-cycled orange-rust. The spores of this rust are cadmium orange in color.

PLATE 92

Manner of germination of the spores of the two orange-rusts. The spores were collected at the same time, placed in Beyerinck agar, and incubated at about 25° C.

A.—Spores taken from leaves of the black raspberry, showing long, wavy germ tubes. ×38.

B.—Spores taken from wild blackberry leaves, showing promycelia and numerous sporidia. ×85.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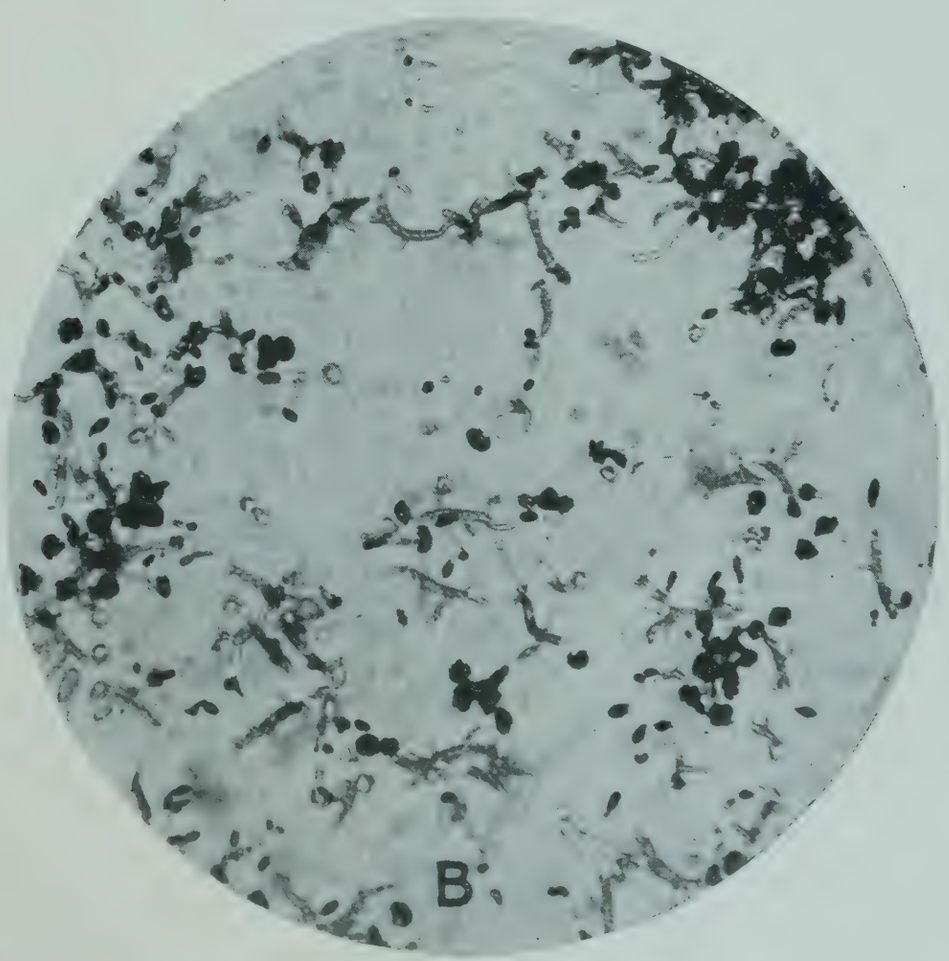
B

PLATE 93

Short-cycled orange-rust. ×100.

1.—Spores collected at Falmouth, Mass., on wild dewberry.
2.—Spores collected at Arlington, Va., on wild blackberry.
3.—Spores collected in Massachusetts on wild blackberry.
4.—Spores collected at Berlin, Md., on cultivated blackberry.
5.—Spores collected at Hyattsville, Md., on wild dewberry.
6.—Spores collected at West Falls Church, Va., on wild dewberry.
7.—Spores collected at Auburn, Ala., on wild dewberry.
8.—Spores collected at Fayetteville, Ark., on wild blackberry.
9.—Spores collected at Potomac Heights, D. C., on wild blackberry.
10.—Spores collected at Morgantown, W. Va., on cultivated blackberry, variety Eldorado.
11.—Spores collected at Blacksburg, Va., on cultivated blackberry, variety Iceberg.
12.—Spores collected at Ithaca, N. Y., on wild blackberry.
13.—Spores collected at Blacksburg, Va., on wild blackberry.
14.—Spores collected at West Falls Church, Va., on wild blackberry.
15.—Spores collected at Gainesville, Fla., on *Rubus cuneifolius*.
16.—Spores collected at Ithaca, N. Y., on wild blackberry.
17.—Spores collected at Chico, Calif., on *R. ursinus*.
18.—Spores collected at Ithaca, N. Y., on wild dewberry.
19.—Spores collected at Arlington, Va., on wild blackberry.
20.—Spores collected at Berkeley, Calif., on *R. parviflorus*.
21.—Spores collected at Hammonton, N. J., on cultivated blackberry.
22.—Spores collected at Fayetteville, Ark., on wild blackberry.
23.—Spores collected at West Falls Church, Va., on wild blackberry.
24.—Spores collected at French Creek, W. Va., on wild dewberry.
25.—Spores collected at Congress Heights, D. C., on wild blackberry.
26.—Spores collected at Connellsville, Pa., on wild blackberry.
27.—Spores collected at Chico, Calif., on *R. ursinus*.
28.—Spores collected at Vienna, Va., on wild blackberry.
29.—Spores collected at Bryan, Ohio, on cultivated blackberry.
30.—Spores collected at Cameron, N. C., on wild blackberry.
31.—Spores collected at Athens, Ohio, on wild blackberry.
32.—Spores collected at Blacksburg, Va., on cultivated blackberry, variety Early King.
33.—Spores collected at Chico, Calif., on *R. ursinus*.
34.—Spores collected at Arlington, Va., on wild blackberry.
35.—Spores collected at Ithaca, N. Y., on wild dewberry.
36.—Spores collected at Mountain Lake, Va., on wild dewberry.
37.—Spores collected at French Creek, W. Va., on wild dewberry.
38.—Spores collected at Blacksburg, Va., on cultivated blackberry.
39.—Spores collected at Blacksburg, Va., on cultivated blackberry, variety Mersereau.
40.—Spores collected at Vienna, Va., on cultivated blackberry.
41.—Spores collected at Ithaca, N. Y., on wild blackberry.
42.—Spores collected at Blacksburg, Va., on cultivated blackberry, variety Ancient Britain.
43.—Spores collected at Janassee Junction, Ga., on wild blackberry.

44.—Spores collected at Thunderbolt, Ga., on *R. procumbens*.
45.—Spores collected at Hyattsville, Md., on wild dewberry.
46.—Spores collected at Hyattsville, Md., on wild blackberry.
47.—Spores collected at Blacksburg, Va., on cultivated blackberry.
48.—Spores collected at Vienna, Va., on wild blackberry.
49.—Spores collected at Willard, N. C., on wild blackberry.
50.—Spores collected at Connellsville, Pa., on wild blackberry.
51.—Spores collected at Auburn, Ala., on wild blackberry.
52.—Spores collected at Butte Creek Canyon, Calif., on *R. ursinus*.
53.—Spores collected at Stark, Fla., on wild blackberry.
54.—Spores collected at Blacksburg, Va., on wild blackberry.
55.—Spores collected at Thunderbolt, Ga., on *R. hispidus*.
56.—Spores collected at Hyattsville, Md., on wild blackberry.
57.—Spores collected at Blacksburg, Va., on wild blackberry.
58.—Spores collected at Hammond, La., on wild blackberry.
59.—Spores collected at Orlando, W. Va., on wild blackberry.
60.—Spores collected at Ithaca, N. Y., on wild blackberry.
61.—Spores collected at Blacksburg, Va., on wild blackberry.
62.—Spores collected at West Falls Church, Va., on cultivated blackberry.
63.—Spores collected at Arlington, Va., on wild blackberry.
64.—Spores collected at Arlington, Va., on wild blackberry.
65.—Spores collected at French Creek, W. Va. on wild blackberry.

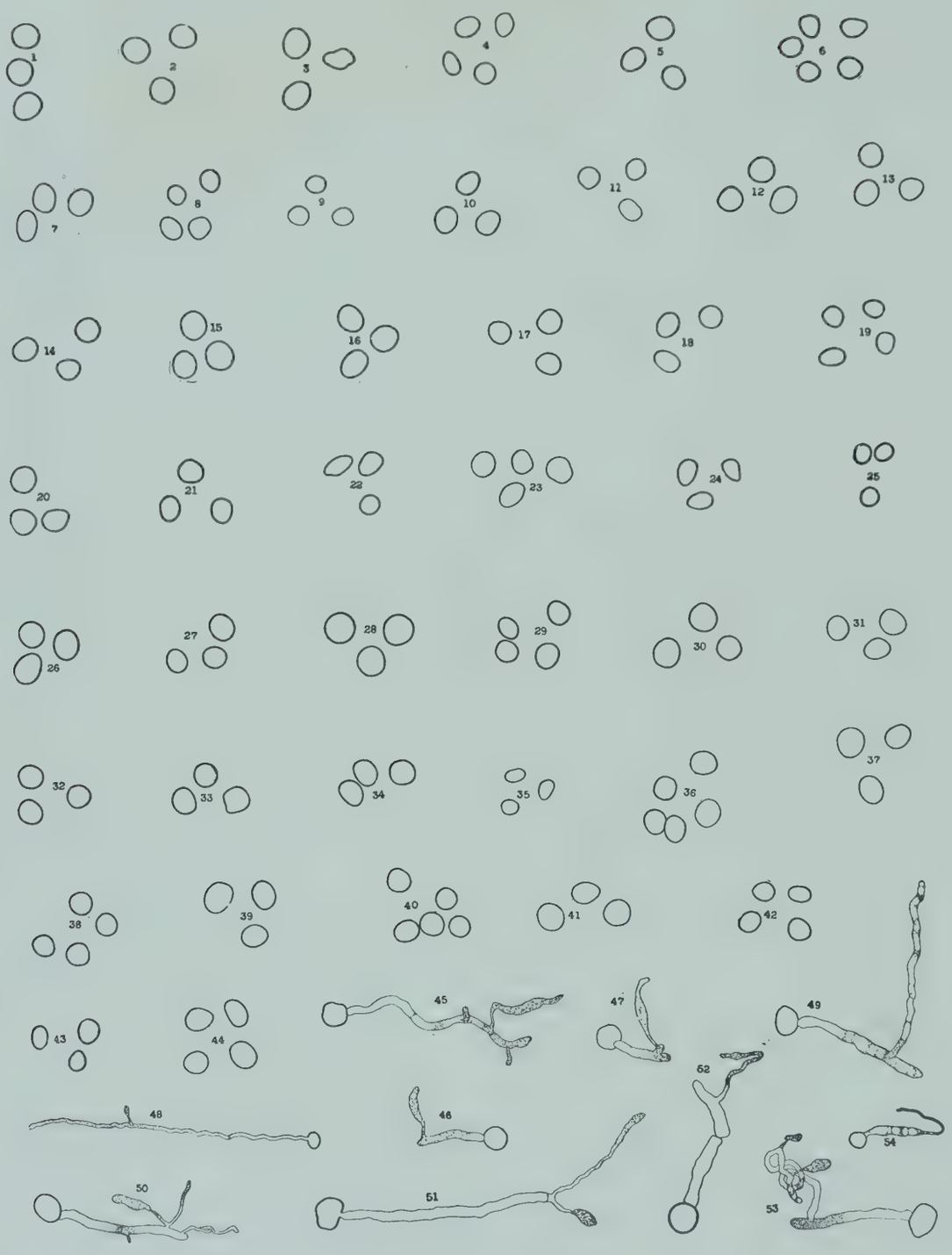
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PLATE 94

Gymnoconia interstitialis. ×100, except figures 48 and 54, which are ×53⅓.

1.—Spores collected at Madrid, Me., on wild blackberry.
2.—Spores collected at French Creek, W. Va., on wild black raspberry.
3.—Spores collected at Glen, N. H., on *Rubus nigrobaccus*.
4.—Spores collected at West Falls Church, Va., on cultivated black raspberry.
5.—Spores collected at Vienna, Va., on cultivated black raspberry.
6.—Spores collected at Old Forge, N. Y., on *R. canadensis*.
7.—Spores collected at Glen, N. H., on wild blackberry.
8.—Spores collected at Mountain Lake, Va., on *R. alleghaniensis*.
9.—Spores collected at West Falls Church, Va., on cultivated black raspberry.
10.—Spores collected at Portland, Me., on *R. canadensis*.
11.—Spores collected at Madison, Wis., on wild blackberry.
12.—Spores collected at Phillips, Me., on wild blackberry.
13.—Spores collected at Portland, Me., on *R. canadensis*.
14.—Spores collected at East Lansing, Mich., on wild blackberry.
15.—Spores collected at Sebago Lake, Me., on *R. triflorus*.
16.—Spores collected in Michigan on wild blackberry.
17.—Spores collected at Old Forge, N. Y., on *R. canadensis*.
18.—Spores collected at Madison, Wis., on wild blackberry.
19.—Spores collected at Old Forge, N. Y., on *R. canadensis*.
20.—Spores collected at West Falls Church, Va., on wild black raspberry.
21.—Spores collected at West Falls Church, Va., on cultivated black raspberry.
22.—Spores collected at West Falls Church, Va., on cultivated black raspberry.
23.—Spores collected at Glen, N. H., on *R. canadensis*.
24.—Spores collected at Mountain Lake, Va., on *R. alleghaniensis*.
25.—Spores collected at French Creek, W. Va., on black raspberry.
26.—Spores collected at Portland, Me., on *R. canadensis*.
27.—Spores collected at Smugglers Notch, Vt., on *R. strigosus*.
28.—Spores collected at Madrid, Me., on wild blackberry.
29.—Spores collected at Old Forge, N. Y., on *R. canadensis*.
30.—Spores collected at Smugglers Notch, Vt., on *R. canadensis*.
31.—Spores collected at Bancroft, Wis., on *R. hispidus*.
32.—Spores collected at Juliet, N. Y., on *R. canadensis*.
33.—Spores collected at French Creek, W. Va., on black raspberry.
34.—Spores collected at Old Forge, N. Y., on *R. canadensis*.
35.—Spores collected at Madison, Wis., on wild blackberry.
36.—Spores collected at Portland, Me., on *R. triflorus*.
37.—Spores collected at Sebago Lake. Me., on *R. triflorus*.
38.—Spores collected at Smugglers Notch, Vt., on *R. canadensis*.
39.—Spores collected at Sebago Lake, Me., on *R. triflorus*.
40.—Spores collected at Rouses Point, N. Y., on black raspberry.
41.—Spores collected at Sebago Lake, Me., on wild blackberry.
42.—Spores collected at Mountain Lake, Va., on *R. alleghaniensis*.
43.—Spores collected at Bound Brook, N. J., on black raspberry.
44.—Spores collected at Glen, N. H., on *R. canadensis*.
45.—Spores collected at Glen, N. H., on *R. canadensis*.
46.—Spores collected at Chain Bridge, near Washington, D. C., on black raspberry.
47.—Spores collected at Chain Bridge, near Washington, D. C., on black raspberry.
48.—Spores collected at Chain Bridge, near Washington, D. C., on black raspberry.
49.—Spores collected at Glen, N. H., on *R. canadensis*.
50.—Spores collected at Glen, N. H., on *R. canadensis*.
51.—Spores collected at Glen, N. H., on *R. canadensis*.
52.—Spores collected at West Falls Church, Va., on black raspberry.
53.—Spores collected at Vienna, Va., on black raspberry.
54.—Spores collected at West Falls Church, Va., on black raspberry.

GERM-FREE FILTRATES AS ANTIGENS IN THE COMPLEMENT-FIXATION TEST

By WILLIAM S. GOCHENOUR

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In the production of germ-free blackleg filtrates, to insure uniformly good results it is of prime importance to check or control properly each lot of culture flasks, so as to know definitely that the blackleg organism alone has been growing therein. After the culture flasks have been inoculated and have been incubated for from six to nine days it is quite simple to remove one or more cubic centimeters of the culture and test it for the presence or absence of aerobic organisms. The detection of foreign anaerobes, however, should any be present, is not at all a simple procedure. Moreover, it would be quite impracticable to resort to the complicated process of anaerobic plating or fishing in the search of contaminating anaerobic microorganisms as a routine procedure with each lot of culture flasks. For this reason serological studies were made with pure germ-free blackleg filtrates to ascertain whether they would act as antigens in the complement-fixation test and, if so, what range of specificity could be obtained therewith, using the results as an index to what a satisfactorily produced product should possess.

Accordingly, blackleg filtrates were prepared, and a horse was repeatedly injected with them at intervals extending over a period of approximately three months. Blood serum drawn from this animal constituted the positive or immune serum. Antigenic titrations were then made, using 0.2 cc. of positive and 0.2 cc. of negative (normal horse) serum; and grading amounts of the germ-free filtrate were added as the antigen. The titration given in Table I will exemplify the character of reaction that has been obtained.

When the filtrate is concentrated over sulphuric acid in vacuo to one-half or one-third its original volume, the antigenic unit and the anticomplementary dose are reduced in the same ratio.

So far as the writer is able to learn by search through the literature, the use of a germ-free filtrate as an antigen in the complement-fixation test is an entirely new phenomenon; and it promises to serve a very important rôle in the separation and differentiation of the spore-bearing anaerobes. With this purpose in mind it is contemplated to parallel this reaction with the other pathogenic spore-bearing anaerobes as *Bacillus edematiens*, vibrion septique, *B. tetanus*, *B. botulinus*, etc.; and evidence of the feasibility of doing this is shown in the tests already made with

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B. botulinus filtrate. Good fixations were obtained by using *B. botulinus* (type B) filtrate with *B. botulinus* (type B) immune serum, but type B filtrate and type A serum would not produce a fixation, nor would type A filtrate produce a fixation with type B serum. Considering that type B immune serum does not protect guinea pigs against type A filtrate, which contains the type A toxin, and vice versa, the absence of fixation when using one type of serum and the other type of filtrate as antigen is quite important from a differential standpoint and also serves to indicate the specificity of the reaction obtainable by this method.

TABLE I.—*Titration of germ-free blackleg filtrate antigen*

Tube No.	Serum.		Physiological salt solution.	Antigen.[c]	Complement.		Hemolytic rabbit serum and sheep corpuscle.[d]	Result.[e]
	Positive.[a]	Negative.[b]						
	Cc.	*Cc.*	*Cc.*	*Cc.*	*Cc.*		*Cc.*	
1	0.2		2	0.05	1	Incubated 1 hour at 37° C.	2	+
1	.2		2	.1	1		2	+
3	.2		2	.2	1		2	+
4	.2		2	.3	1		2	+
5	.2		2	.4	1		2	+
6	.2		2	.5	1		2	+
7	.2		2	.6	1		2	+
8	.2		2	.7	1		2	+
9	.2		2	.8	1		2	+
10	.2		2	1.0	1		2	+
11	.2		2	2.0	1		2	+
12	.2		2		1		2	−
1		0.2	2	.05	1		2	−
2		.2	2	.1	1		2	−
3		.2	2	.2	1		2	−
4		.2	2	.3	1		2	−
5		.2	2	.4	1		2	−
6		.2	2	.5	1		2	−
7		.2	2	.6	1		2	−
8		.2	2	.7	1		2	±
9		.2	2	.8	1		2	+
10		.2	2	1.0	1		2	+
11		.2	2	2.0	1		2	+
12		.2	2		1		2	−
13		.2	2		1		2	−
14		.2	2				2	+

[a] Horse serum hyperimmunized to germ-free blackleg filtrate.
[b] Normal horse serum.
[c] Germ-free blackleg filtrate.
[d] Hemolytic system employed consisted of a 3 per cent suspension of sheep red cells, 2½ units of hemolytic amboceptor, and 1½ units of complement, the latter being titrated against the amboceptor and sheep cells.
[e] + indicates complete inhibition of hemolysis; ±, partial inhibition of hemolysis; and −, no inhibition of hemolysis.

Since a blackleg filtrate produced from a pure culture of *Bacillus chauveaui* and grown under favorable conditions will possess antigenic value in the quantities shown in the preceding table, if a filtrate were encountered that failed to approximate such a titre then only would it

seem necessary to resort to the anaerobic cultural examination of the culture flasks. Calves inoculated with blackleg filtrate showing a satisfactory antigenic value were rendered sufficiently immune, after a period of three to four weeks, to withstand intramuscular injections of 100 to 200 mgm. of virulent blackleg muscle powder, a quantity sufficient to kill unvaccinated calves in two to three days.

Failure of a blackleg filtrate to possess an antigenic titre of from 1/10 to 1/20 the anticomplementary dose should arouse the suspicion that the blackleg organism did not grow under favorable conditions, that some contamination is present, or that the organism being used was not the blackleg organism at all.

CONCLUSION

From the data at hand it can be said that—

(1) A blackleg filtrate produced under favorable conditions will possess a distinct antigenic value demonstrable by the complement-fixation test.

(2) Those blackleg filtrates that conferred a solid immunity on calves were found to possess a high antigenic titre.

(3) The complement-fixation reaction should be of much value as a laboratory control test to determine whether the filtrate has been produced under conditions favorable to the blackleg organism or whether the blackleg organism has been supplanted in part or wholly by contaminating anaerobic microorganisms.

(4) Botulinus filtrate also acts as an antigen in the complement-fixation test when type B serum is used with type B filtrate but fails to cause fixation when one type of serum is used with the other type of filtrate as antigen.

(5) The phenomenon of germ-free filtrates acting as antigens in the complement-fixation test is new and promises to play an important part in the differentiation of the spore-bearing anaerobes, more especially those having closely similar cultural characteristics.

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MOSAIC DISEASE OF CORN [1]

By E. W. BRANDES

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DISTRIBUTION

In connection with an investigation of the mosaic disease of sugar cane, a similar disease of corn has been observed by the writer on several occasions in widely separated regions.[2] On April 18, 1919, corn of an unknown variety was seen to be affected with typical mosaic symptoms in a field just west of Peñuelas, P. R. The percentage of affected plants was small, however, only 20 individuals being found in the field of some 5 acres. The corn averaged about 24 inches in height at this time and was planted between rows of sugar-cane stubble which had not been completely killed out in preparing the land for the corn. All the sugar cane was affected with mosaic. In July, 1919, corn of the White Creole variety was seen at the Sugar Experiment Station, New Orleans, La., in which the same condition was apparent. This corn was more than half grown, and the typical streaking of the leaves was somewhat obscured by certain leafspot diseases, among them the leafspot caused by *Physoderma zeae-maydis*, by which the corn was severely attacked. About 10 per cent of the plants in the field were affected with mosaic. In adjoining fields of sugar cane nearly 100 per cent of the plants were affected with the sugar-cane mosaic. In 1920 corn of the same variety was examined early in the season, and a much more serious infestation was found. The corn had been planted following sugar cane, and occasional diseased stools of the latter not killed by the plow were found all through the corn field. More than 30 per cent of the corn plants were affected. The cases were more abundant in the vicinity of the sugar-cane stools referred to above, but cases could be found many rods from any living cane. Of course, it is possible that a stool of cane had sprouted between the rows in such a situation and later had been killed by the cultivator. In May, 1920, identical cases of mosaic were seen in a field of corn near Cairo, Ga. As in the cases reported previously, a neighboring field of sugar cane was slightly infested with mosaic.

[1] The study of this disease was undertaken on account of its relation to sugar-cane mosaic.

[2] BRANDES, E. W. THE MOSAIC DISEASE OF SUGAR CANE AND OTHER GRASSES. U. S. Dept. Agr. Bul. 829, 26 p., 5 fig., 1 col. pl. 1919.

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Diseases of corn bearing a decided resemblance to the one in question have been reported from other countries. Dr. H. L. Lyon states [1] that in the Hawaiian Islands a disease of corn which resembles sugar-cane mosaic is very serious. William H. Weston [2] describes a disease of corn in Guam which may be identical with the one under discussion. He mentions yellowing and dwarfing among the symptoms and states that the leaves exhibited mottling and striping.

VARIETAL SUSCEPTIBILITY

Just enough work has been done on varietal susceptibility to prove that all varieties of corn do not respond in the same way. The writer has never seen such excessive injury as that described for the unknown variety in Guam by Weston. In Louisiana the injury to corn of the White Creole variety, while marked in some individuals, was not excessive, excepting when the plants were infected early in the spring. The variety U. S. Select No. 182 is very susceptible to mosaic, but is not especially injured by it. Golden Bantam sweetcorn could not be infected in the greenhouse by methods which were successful with U. S. Select No. 182. Golden Bantam was planted unprotected in a greenhouse with hundreds of infected sugar-cane and sorghum plants. The corn aphis quickly migrated to the young corn plants from diseased sorghum in great numbers, but no cases appeared among the Golden Bantam seedlings. It seems probable that this variety is immune.

IMPORTANCE

No figures are available on the amount of loss sustained on account of injury to corn. The writer is inclined to believe that in this country no great damage has been done thus far. Probably the disease was introduced on sugar cane within comparatively recent years, in which case it may become more important in the future. At present, however, our chief concern is with its relation to the sugar-cane crop. Corn is almost invariably used in the rotation on sugar-cane land, so that no plantation is ever without corn in some of its fields. This means, of course, that the possibility for spread of the disease is greatly increased. Overwintering by the virus has been demonstrated only in the vegetative portions of the sugar-cane plant, but the existence of other graminaceous hosts certainly complicates the problem of control.

SYMPTOMS

In corn as in sugar cane the most conspicuous symptom of mosaic is the streaked and irregularly mottled appearance of the leaves. In corn, however, the lower, older leaves have a greater tendency to resume their normal color, so that it is sometimes difficult to demonstrate the

[1] In verbal communication, January, 1920.

[2] WESTON, W. H. REPORT ON THE PLANT DISEASE SITUATION IN GUAM. Guam Agr. Exp. Sta. Rpt. 1917, p. 45–62. 1918.

mosaic patterns in such leaves. In the youngest leaves, either the normal dark green or the pallid, affected tissue may predominate in a given specimen, but the latter condition is most frequently met with. In such cases the areas which remain normal are in the shape of broken or interrupted streaks or lines extending in the general direction of the long axis of the leaf (Pl. 95), and the contrast in color between these areas and the surrounding pallid areas is very decided. The streaks vary greatly in size, ranging from mere points to elongated "islands" of dark green 2 or 3 cm. or more long and several millimeters wide. The margins of such streaks may be straight or undulating. In most cases the mosaic pattern is more prominent at the base of the leaf, where it diverges from the leaf sheath. Where the normal dark green is predominant, the light green, affected tissue appears usually as a very fine mottling or as irregular elongated streaks on the darker background. From the foregoing description it can be seen that the patterns vary considerably, and yet they have certain general characteristics which make it almost impossible to confuse this condition with any other affecting the leaves.

Infected plants are always lighter in color than healthy plants. When viewed from a distance such plants can be picked out with a fair degree of accuracy on this account. The top of the plant is especially pale, much more so than normal freshly unrolled young leaves. In some cases the color becomes decidedly yellow. In this connection it must be stated that the pallid color referred to heretofore as characteristic of the diseased areas is not a yellowish green but a lighter or more dilute tint of the normal green. In plants which become markedly yellow a decided stunting of the whole plant takes place. At no time has a case been observed to terminate fatally, but certainly considerable injury results from the lack of functioning chloroplastids, and where a large percentage of the plants are affected the loss due to decreased size of ears is appreciable. When infection takes place early in the growing season, partial or complete sterility of the ears results. This serious feature of the disease was first noticed in Louisiana in 1920. In May, 1920, the writer tagged 20 diseased and 10 healthy plants in a field of White Creole corn. The diseased and healthy plants were equally vigorous to all appearances at that time and were in the same rows, alternate diseased and healthy plants in the same row being selected as far as it was practicable. When the crop was harvested in August, 17 of the diseased plants were found to be completely sterile, while 3 of them had set a few scattered kernels. The 10 healthy plants were normal, excepting for slight corn earworm injury, and produced large well-filled ears (Pl. 96).

During the course of experiments in the greenhouse several cases of apparent recovery have been observed. Plants which became infected and exhibited the typical symptoms resumed their normal color after several weeks. These plants were held under observation until the ears were mature, but there was no recurrence of the mosaic symptoms.

This interesting behavior was also noted in stools of crabgrass (*Syntherisma sanguinalis*) and foxtail (*Chaetochloa lutescens*). There were no changes of growing conditions that could be correlated with these apparent recoveries. In this connection it may not be out of place to record that suckers from diseased stools of sugar cane and sorghum have been observed to come up with no sign of mosaic. These instances are by no means common, but several have been seen in both plants mentioned.

INSECT TRANSMISSION OF CORN MOSAIC

The manner in which corn mosaic is transmitted to healthy plants and the relation of this disease to mosaic in other grasses was demonstrated by the following experiments.

EXPERIMENT 1.—On March 12, 1920, 12 corn plants of the variety U. S. Select No. 182 were placed in each of two insect-proof cages. All of the plants were from the same lot of seed furnished by the Office of Cereal Investigations. The seed had been planted in one flat, and the seedlings were replanted in 5-inch pots on the date of removal to the cages. They were then 12 inches tall. About 12 individuals of *Aphis maydis* were carefully removed by means of a small camel's-hair brush from sorghum plants affected with mosaic to each corn seedling in one of the cages. The sorghum plants had been infected by aphids from mosaic sugar cane. Twelve aphids were transferred in the same way from healthy sorghum to each of the corn seedlings in the adjoining control cage. On March 28, 6 of the 12 corn seedlings in the first cage showed typical signs of mosaic in the two youngest leaves. On April 6, 8 of the plants, or 66⅔ per cent, were typical cases. The 12 control plants remained healthy up to the time of removal several weeks later.

EXPERIMENT 2.—On April 6, 1920, 20 corn seedlings, variety U. S. Select No. 182, in 5-inch pots were placed in each of two insect-proof cages in the greenhouse. Several specimens of *Aphis maydis* were transferred from infected corn plants to each corn seedling in the first cage. Aphids from healthy corn in another greenhouse were placed on each corn plant in the second control cage, which was used as a control. On May 4, 7 of the corn seedlings in the first cage were found to be infected. On May 28, 15 of the 20 plants were observed to be unmistakable cases. The aphids had increased enormously in both cages. Not a single case could be found in the control cage, nor had any appeared up to June 25, although the plants had been repotted twice and were approaching maturity.

These experiments demonstrate conclusively that provision is made for almost unlimited dispersal of the virus through the medium of the corn aphis. There is no reason for supposing that transmission in nature is limited to this insect or to this method. It is not yet known whether the virus can survive the winter in seed, but experiments are now under

way that may throw some light on this phase of the problem. It has been proved that the virus of corn mosaic is identical with that of sugar-cane and sorghum mosaic, so that even if it is found not to be seed-borne, perpetuation of the disease in the perennial grasses would explain its appearance on corn in the spring.

Artificial transmission of the disease by means of inoculation with expressed cell sap of affected plants has not been attempted for corn. This method has proved successful in sugar cane, however,[1] and there is little doubt that the infectious material is contained in the cell sap of corn. Just what this infectious material is can not be stated definitely, but the evidence points strongly toward a living organism. No evidence incompatible with this view has been put forward for any mosaic disease, excepting the failure to demonstrate any visible organism.

CONTROL

Control measures for this disease must be based fundamentally on the removal of sources of the inoculum. So far as is known the only sources of inoculum are the living host plants. Destruction of these plants, then, will effectively eradicate the disease from any region. Practically, the destruction of all affected host plants presents almost unsurmountable obstacles. An immense amount of sugar cane is now infected in the River District of Louisiana and in southern Georgia. Destruction of large numbers of plants by roguing or plowing up is viewed with great concern by the planters, most of whom oppose any plan to control the disease by eradication. The substitution of immune varieties of corn as well as cane does not offer any immediate solution, since the most susceptible varieties happen to be the ones most esteemed. Elimination of this disease is dependent upon the education of the planter to an understanding of its seriousness. When this is accomplished public sentiment will permit of the passage of compulsory roguing and quarantine laws, which will be necessary before any hope can be entertained of eliminating the disease.

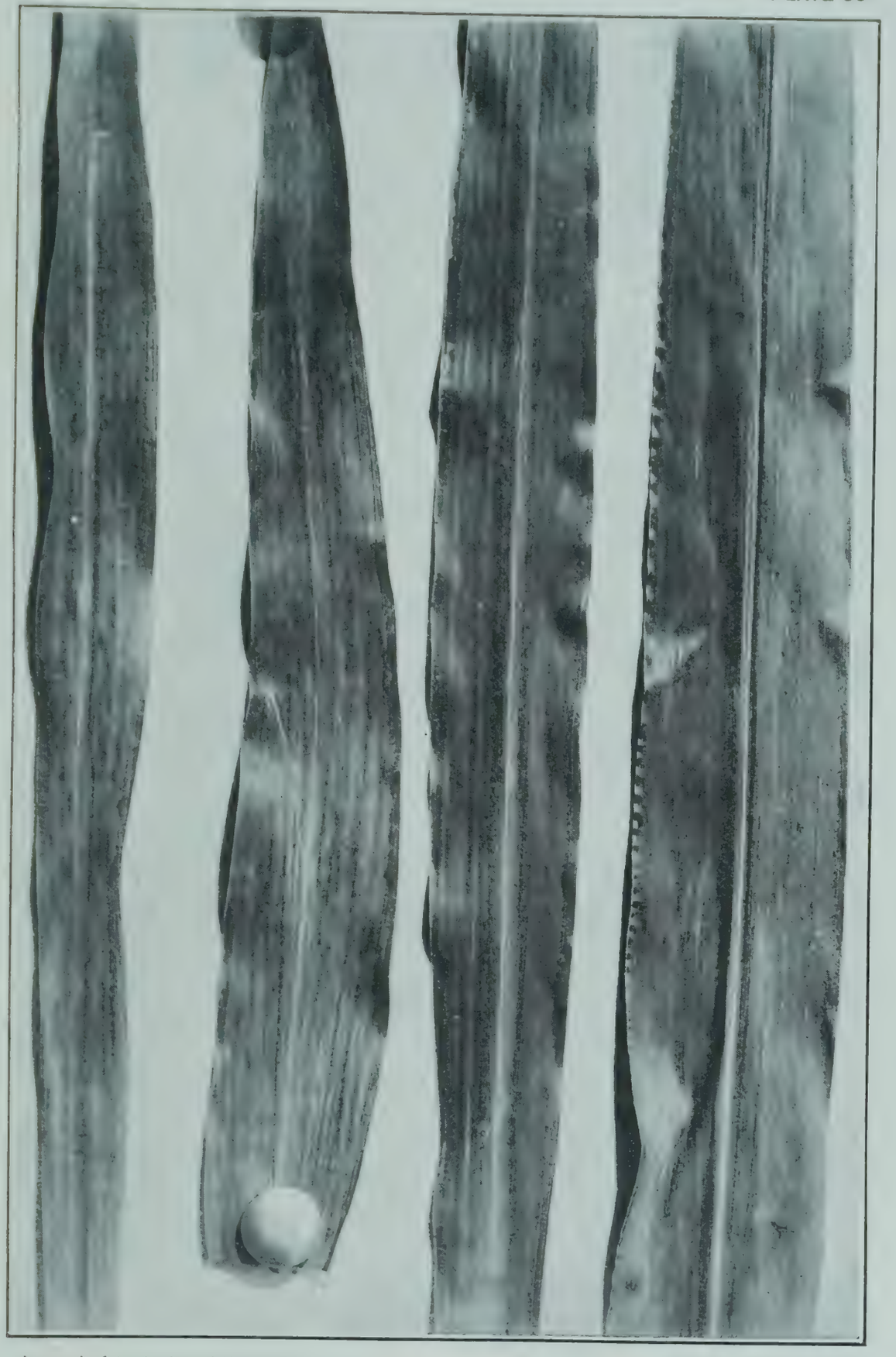
[1] BRANDES, E. W. ARTIFICIAL AND INSECT TRANSMISSION OF SUGAR-CANE MOSAIC. *In* Jour. Agr. Research, v. 19, no. 3, p. 131–138. 1920. Literature cited, p. 138.

PLATE 95

Mosaic disease of corn:

The first leaf at the left shows the typical interrupted streaks of normal green in a pallid green background. The next leaf shows a more irregular, mottled pattern. In these specimens the normal green was similar to "nickel green" and the pallid green was similar to "rejame green" in Ridgeway.[1] The two leaves at the right are from a healthy plant and are presented for comparison.

[1] RIDGEWAY, Robert. COLOR STANDARDS AND COLOR NOMENCLATURE. 43 p., 53 col. pl. Washington, D. C., 1912.



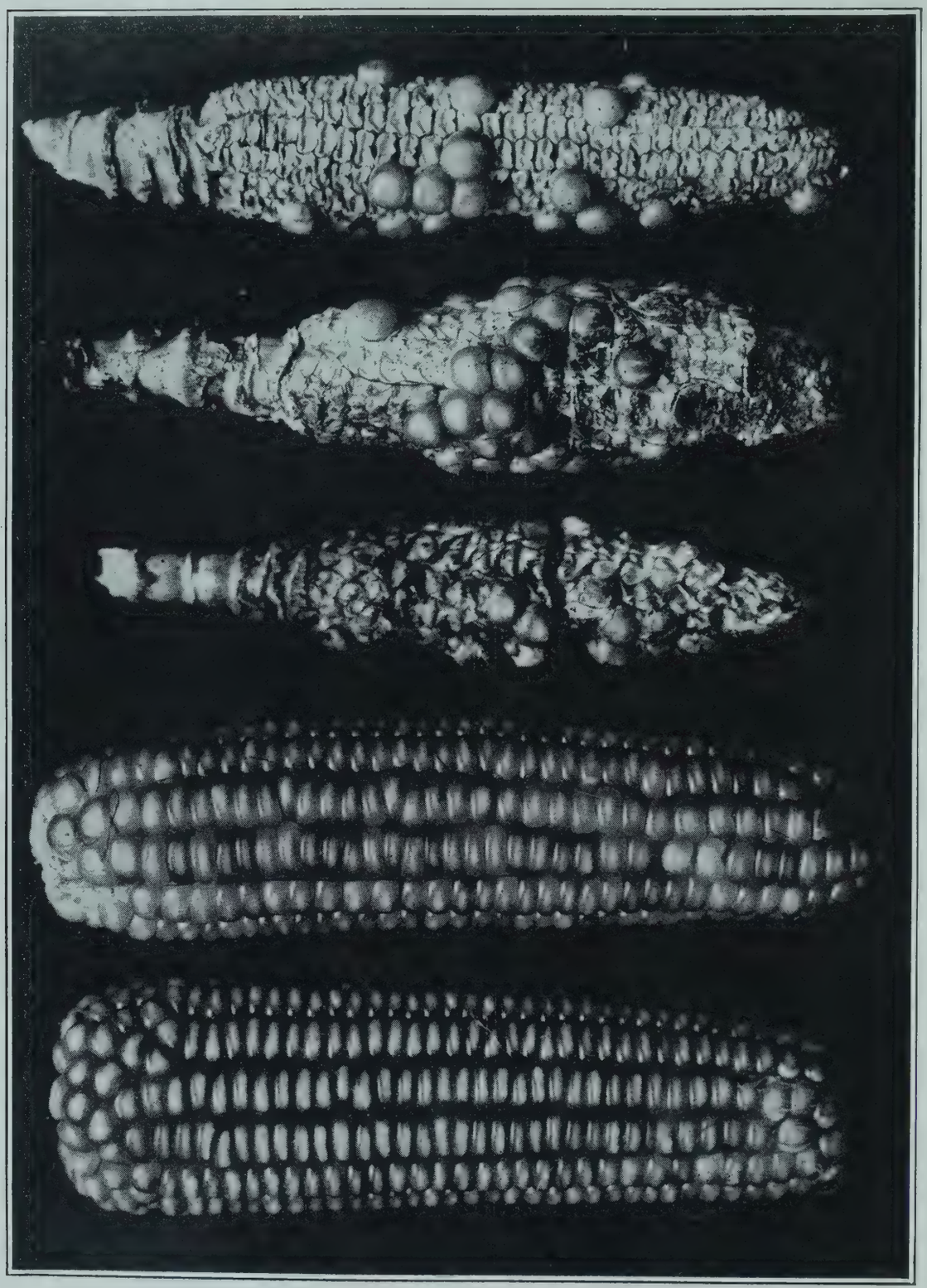


PLATE 96.

Mosaic disease of corn: Effect of early infection on the ear. White Creole variety.

The three ears at the top were produced by plants naturally infected in the field. In 17 out of 20 marked plants no kernels at all were developed.

The two lower ears are typical of all ears produced by healthy plants in the same row with the diseased plants.

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GENETICS OF RUST RESISTANCE IN CROSSES OF VARIETIES OF TRITICUM VULGARE WITH VARIETIES OF T. DURUM AND T. DICOCCUM [1]

By H. K. HAYES, *Head of Section of Plant Breeding, Division of Agronomy and Farm Management, Department of Agriculture, University of Minnesota,* JOHN H. PARKER, *Scientific Assistant,* and CARL KURTZWEIL,[2] *Assistant Pathologist, Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture*

INTRODUCTION

The black stemrust (*Puccinia graminis*) of small grains causes enormous losses. Reduction in yield of from 10 to 50 per cent of the wheat crop is common. At irregular intervals the black stemrust of wheat causes almost complete failure, especially in the spring-wheat area of the upper Mississippi Valley. Control of this disease, which develops into such terrific epidemics, is impossible by any method now available to the individual grower. For this reason the development of resistant varieties assumes great importance. While the barberry eradication campaign now being carried on over a wide area will certainly reduce the amount of rust, local outbreaks may perhaps be expected even after barberries have apparently been eradicated. The attempt to develop resistant varieties, therefore, should continue. There is every reason to hope that the stemrust problem can be solved by barberry eradication and the development of resistant wheat varieties.

When the present study was outlined, the evidence seemed to show that parasitic action of the rust was constant. Recent extensive studies (*22*, *23*)[3] have confirmed this view and indicate that the bridging hypothesis (*11*), which was supposed to account for the increase or decrease in

[1] Published with the approval of the Director as Paper 187, Journal Series, Minnesota Agricultural Experiment Station. Cooperative investigation between the Minnesota Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture.

[2] The breeding of spring wheat for rust resistance was begun by Dr. E. M. Freeman and E. C. Johnson in 1908 and has been continued without interruption until the present time. The present cooperative arrangement between the Division of Plant Pathology and Botany and the Section of Plant Breeding, Division of Agronomy and Farm Management, of the University of Minnesota, was made in the spring of 1916. The writers wish to acknowledge the helpful cooperation of Dr. E. M. Freeman and Dr. E. C. Stakman in this investigation.

[3] Reference is made by number (italic) to "Literature cited," pp. 541–542.

virulence of the rust, is probably incorrect. More recent investigations of the wheatrust fungus have shown that there are numerous biologic forms (*25*) which can be differentiated only by their action on various pure-line wheat varieties. This is a very serious obstacle to the production of rust-resistant varieties by breeding, although the fact that Khapli (C I 4013),[1] an emmer imported from India, is resistant to all biologic forms so far isolated shows that the problem is not entirely hopeless.

Former breeding investigations have determined which varieties of wheat are commonly resistant to stemrust at University Farm, St. Paul, and have also indicated the behavior of rust resistance in crosses. In the light of this information it was decided to make a careful genetic study of one or two crosses, hoping thus to solve the plant-breeding phase of the rust-resistance problem. The second generation of the crosses reported in this paper had already been studied before it was known that there were sometimes numerous biologic forms of the rust in the same locality. It seemed worth while to complete the study of inheritance of rust resistance in these crosses by growing a small F_3 family of each F_2 plant which produced viable seed. All barberry bushes were removed from the immediate vicinity of the rust plot early in the spring of 1918, and the artificially induced epidemic was produced with a known racial strain of the biologic form *Puccinia graminis tritici* Erikss. and Henn. Therefore, the greater part, if not all, of the rust infection present during the season of 1918 was due to this one biologic form. One uredinium found on Kanred (C I 5146), which is known to be resistant to the strain which was used to induce the epidemic, proved to belong to another biologic form.

The present paper is a report of the inheritance of rust resistance in its correlation with botanical and morphological characters of crosses between *Triticum vulgare* with varieties of *T. durum* and *T. dicoccum*.

SOME PREVIOUS CROSSES OF WHEAT SPECIES

Because of the many differential characters and the great economic importance of the crop, wheat has been frequently used in studies of the laws of inheritance. Vilmorin (*26*, *27*) reported quite extensive tests of crosses between *Triticum sativum* L., *T. turgidum*, *T. durum* Desf., *T. polonicum* L., and *T. spelta*. From the Mendelian standpoint the results obtained are interesting. He observed remarkable uniformity in the F_1 generation, wide diversity in the F_2 generation, and states that the predominating force after the F_3 generation is that of heredity, which compels the plants to reproduce their characters in their immediate descendants. Vilmorin placed spelt and common wheats in one group and poulard and durum in another, because he found that either spelt or common crossed with poulard or durum produced all four types in the

[1] Cereal investigations number.

segregating generations. These types were easily fixed after several years of selection. The four types were believed to have a common ancestry and to belong to one botanical species. Unsuccessful attempts were made to cross these species with *T. monococcum* L. This led Vilmorin to conclude that *T. monococcum* belonged to a separate species.

Tschermak (*25*) confirmed Vilmorin's conclusions regarding the production of common, durum, spelt, and poulard forms from crosses when the groups differed in the solid and hollow stem character. He stated that the polonicum type was obtained only when it was used as one of the parents. Relationships were illustrated on a factor hypothesis by assuming (1) that *Triticum polonicum* contained two dominant factors, (2) that common wheat lacked these factors, and (3) that durum contained one of these factors but not the other. Tschermak also thinks that *T. monococcum* is different from other wheat species. He obtained hybrids between *T. monococcum* and *T. vulgare* and one F_2 plant, which soon died.

Blaringhem (*6*), however, succeeded in crossing *Triticum durum* and *T. polonicum* with *T. monococcum*. Sterility was at first of frequent occurrence in these crosses, but in later generations it was much less common.

Explorations by Aaronsohn in 1906 (*1*) confirm the experimental evidence cited above. A wild emmer, *Triticum dicoccum dicoccoides*,[1] found in 1906, is interesting because it tends to confirm the report that such an emmer was collected as early as 1885.

Crosses between Black Winter emmer and Fultzo-Mediterranean (*15*) had strongly keeled glumes with hard, adherent chaff in the F_1 generation. The F_2 plants varied widely in type and exhibited transgressive segregation for some characters. There was considerable sterility in this cross. The hairy chaff and black color of the emmer parent were linked in inheritance.

Freeman (*12*) found evidence of linkage between high ratio of width to thickness of head and hardness of grain in a cross between durum wheat and a variety of bread wheat. The bread wheat parent had a square head with soft, opaque grains, while the durum parent had a much flattened head and produced hard, translucent grains.

In a recent article on heredity of quantitative characters in wheat (*13*) a cross between durum and common wheat is reported. It gave normally vigorous plants in the F_1 generation. In the F_2 generation, however, many seeds failed to germinate; and among those with a normal vegetative development were found plants exhibiting every degree of sterility, from perfectly sterile to fertile plants.

Linkage has been reported by Engledow and Biffen in crosses between Rivet, *Triticum turgidum*, and common Fife wheat. Gray glume color

[1] From a cross between durum and common varieties, Love and Craig have produced a form which closely resembles the wild emmer. Love, H. H., and Craig, W. T. THE SYNTHETIC PRODUCTION OF WILD WHEAT FORMS. *In* Jour. Hered., v. 10, no. 2, p. 51-64, illus.

(*4*) was always found associated with hairy chaff, and partial linkage (*10*) was found between the factors for black color and the factors for glabrous chaff.

Since sterility has been found by many investigators in wheat crosses and has been confirmed by the results presented in this paper, it seems rather difficult to reach any conclusion regarding linkage, because some combinations may be eliminated.

The inheritance of the principal botanical characters of our cultivated wheats is well known and, therefore, need not be summarized in this paper. The inheritance of beards will be mentioned in connection with our results on sterility. In crosses between the so-called beardless wheats such as Marquis and Bluestem and a bearded variety, the F_1 generation has intermediate awns and in the F_2 generation a 1 to 2 to 1 ratio is obtained. Fully bearded plants breed true in the F_3 generation. Howard and Howard (*14*) found that there are two classes of wheats with short awns which, when crossed, give fully bearded plants in the F_2 generation and breed true in the F_3 generation. Likewise, crosses between bearded and true beardless forms gave 1 fully bearded plant in the F_2 generation out of 16 plants. The fact of interest for our studies is that fully bearded plants breed true for this character.

PREVIOUS STUDIES ON INHERITANCE OF RUST RESISTANCE

The most successful attempt to breed rust-resistant wheats was made by Biffen (*2*, *3*, *5*), who found that resistance to striperust (*Puccinia glumarum* Erikss. and Henn.) was a recessive character. Definite segregation occurred in the F_2 generation, and forms bred true in the F_3 generation, the ratio of resistant to susceptible in the segregating families being 1 to 3. From the practical standpoint these experiments have been very valuable. A new variety, Little Joss, was produced, which, because of its rust resistance, yields more on the average than susceptible sorts and has desirable milling characters.

Nilsson-Ehle (*20*) has likewise made studies of the inheritance of resistance to striperust. Distinct dominance of susceptibility was seldom found. Ordinarily the F_1 generation was intermediate, and in other cases resemblance to one or the other parent was observed. Segregation was obtained in the F_2 generation, but without definite ratios. Transgressive segregation occurred, forms being obtained which were more susceptible than the susceptible parent and others which were more resistant than the resistant parent. The results were explained on the basis of multiple factors.

While many observations have been made on resistance of wheat varieties, the two experiments cited above are the only carefully controlled studies so far reported which show the mode of inheritance.

METHODS OF STUDYING INHERITANCE OF RUST RESISTANCE

In the studies here recorded crosses were made between Marquis and resistant durum and emmer wheats. Precautions were taken to protect the emasculated heads from foreign pollen. The F_1 plants were grown in individually spaced plots, and seed from each F_1 plant was grown separately. The F_2 families of crosses between the same parent varieties gave similar results and were considered as a single cross. No effort was made with either the F_1 or F_2 plants to protect them from natural crossing, and an error was thus introduced which will be discussed later.

The correlation between resistance in the F_1 and the F_2 generations gave unusual results which indicated that some uncontrolled factor was causing complications. For example, the F_1 cross between emmer and Marquis which was grown in 1916 appeared resistant, while in the F_2 generation which was grown in 1917 the number of resistant plants was much smaller than would be expected if resistance were a dominant character. This led to the belief that very likely more than one biologic form of stemrust was present in 1917.

Each F_2 plant which produced viable seed was tested in 1918. As previously mentioned, the barberry bushes were removed from the immediate vicinity of the rust plot early in the spring of 1918. An epidemic was obtained with a known strain of *Puccinia graminis tritici* which had been cultured in the greenhouse by the Section of Plant Pathology for several generations. This strain had been tested repeatedly on varieties of wheat and proved to be constant.

The 1918 results have been used to determine the resistance or susceptibility of F_2 plants which have been grown the previous season. The F_3 as well as the F_2 data have been used as a basis for placing the F_2 plants in certain botanical groups, for the problem was chiefly to determine the mode of inheritance and correlation of resistance or susceptibility with those botanical characters which are commonly used in differentiating wheat species, some of which are also of economic importance.

STERILITY IN THE CROSSES OF MARQUIS WITH DURUM AND EMMER VARIETIES

In order to determine whether there is any interrelation between botanical characters and rust resistance, the data for each F_2 plant were taken in a correlated manner. The practical significance is obvious. For example, if durum head and seed characters were rather closely linked with rust resistance in inheritance, it would be necessary to grow a larger F_2 population to obtain the desired form than if each character were inherited independently. In deciding regarding possible linkage it is important to know whether sterility is involved in the crosses.

Sterility might cause the elimination of certain gametic or zygotic combinations, thus actually eliminating the sort desired. Zygotic combinations are sometimes eliminated as is the case with the homozygous yellow mouse combination (7, 17) and with lethal factors in Drosophila (19). In some cases gametic combinations are eliminated. Such eliminations occur as a result of pollen or ovule abortion.

POLLEN ABORTION

The presence of shriveled or abortive pollen grains is one means of recognizing sterility. The method here used was to shake out pollen from the heads upon a clean glass slide and then place a minute drop of fuchsin on the pollen, then a drop of lactic acid, and a cover glass.[1] By this method pollen was preserved for several weeks and could be studied when it was convenient.

The parent plants and F_1 crosses were grown in 6-inch pots in the greenhouse. A small percentage of small, globular, clear pollen grains were observed. These, together with the occasional shriveled grains, were counted as sterile. The results of these counts are given in Table I.

TABLE I.—*Counts of sterile pollen grains in wheat species and F_1 crosses between them*

	Variety.	Good pollen.	Poor pollen.
Parental species:			
Triticum vulgare	Marquis	513	4
Triticum durum	Mindum	135	2
Triticum durum	Kubanka (C I 2094)	122	3
Triticum dicoccum	Emmer (Minn. 1165)	169	0
F_1 crosses:			
Marquis × emmer (Minn. 1165)		475	19
Emmer (Minn. 1165) × Marquis		340	37
Kubanka (C I 2094) × Marquis		113	9
Marquis × Kubanka (C I 2094)		151	20
Marquis × Mindum		101	12

These results show that there is a larger percentage of shriveled and abortive grains in the crosses than in the parental varieties. There is also an indication of more pollen abortion in the durum-Marquis crosses than in the cross between emmer and Marquis.

COMPARISON OF NUMBER OF SEEDS SET IN F_1 GENERATION AND PARENTS

As a further test of sterility, counts were made of the number of barren florets in several F_1 crosses and their parents.

There are two or more flowers in each wheat spikelet, and usually two or three kernels mature. The outer florets of each spikelet are usually most vigorous, and when only two florets per spikelet produce kernels these are usually the outside ones. Therefore, the two outer florets of

[1] Outlined to the writers by Dr. C. O. Rosendahl, Professor of Botany, University of Minnesota.

each spikelet were examined. The result of this examination, together with the percentage of barren florets, is summarized in Table II.

TABLE II.—*Number of florets not setting seed in Triticum vulgare, T. durum, T. dicoccum, and F_1 crosses of T. vulgare with T. durum and T. dicoccum*

Variety or cross.	Classification.	Number of heads.	Number of florets examined.	Number of good seed.	Number of very badly shriveled seed.	Percentage of barren florets.
Marquis	*Vulgare*	15	369	341	14	3.8
Preston (Minn. 188)	do	17	528	500	1	5.1
Pioneer	do	26	804	761	1	5.2
Average						4.7
D–4	*Durum*	16	538	499	13	4.8
Iumillo (C I 1736)	do	16	494	464	1	5.9
Kubanka (C I 2094)	do	25	898	864	2	3.6
Acme	do	18	622	604	0	2.9
Average						4.3
Emmer (Minn. 1165)	*Dicoccum*	22	630	611	6	2.1
Kubanka (C I 2094) × Marquis.	*Durum* × *vulgare*	12	426	206	9	49.5
Acme × Preston	do	3	104	62	5	35.6
D–4 × Pioneer	do	9	262	97	17	56.5
Average						47.2
Marquis × Kubanka (C I 2094).	*Vulgare* × *durum*	49	1,692	704	97	52.7
Marquis × Iumillo (C I 1736).	do	4	135	84	9	31.1
Pioneer × D–4	do	9	296	128	11	53.0
Preston × Acme	do	10	348	167	10	49.1
Average						46.5
Emmer × Marquis	*Dicoccum* × *vulgare*	14	410	299	17	22.9
Emmer × Preston	do	13	446	293	25	28.7
Average						25.8
Marquis × emmer	*Vulgare* × *dicoccum*	9	270	184	10	28.2
Preston × emmer	do	3	94	62	4	29.8
Average						29.0

The main spike of individual plants of the parent and crosses was used for this study. There was an average of 4.7 per cent of barren florets in three varieties of *Triticum vulgare.* In four varieties of *T. durum* there was an average of 4.3 per cent, while emmer (Minnesota 1165) produced only 2.1 per cent of florets which formed no kernels. Since these are presumably homozygous, it seems fair to conclude that the percentages given show the average number of florets which did not set seed on account of causes other than sterility.

Three F_1 crosses were studied in which a durum sort was the female parent and four in which durum was the male parent. The average

percentages of barren florets were 47.2 and 46.5, respectively. There was about the same percentage of barrenness in emmer × Marquis, emmer × Preston, and reciprocals—namely, 25.8 when emmer was the female parent and 29 when emmer was the male parent. Thus, there is apparently more sterility in the durum-Marquis cross than in the cross between emmer and Marquis.

Although no cytological examination was made to determine the time of degeneration, it seems very likely that there is ovule as well as pollen abortion. Barren florets, however, might be due to incompatibility of certain genetic combinations or to slow growth of the pollen tube which has been shown to occur in some species crosses (*8*, *9*).

NATURAL CROSSES AS A POSSIBLE INDICATION OF STERILITY

In 1917 the F_2 generation of durum × Marquis and durum × Haynes Bluestem, as well as the parent sorts, were grown together. Marquis is an awnless, glabrous chaffed wheat, Bluestem is an awnless wheat and has pubescent chaff, while the durum varieties used have glabrous chaff and are bearded. In the F_2 generation of the durum-Marquis cross there were a few individual plants with hairy chaff. Since these may have been the result of natural hybridization, these plants were eliminated from further consideration.

In the F_3 families of the durum-Marquis cross, each of which came from an individual F_2 plant, there were some hairy-chaffed plants. In some families the number of plants with hairy chaff was rather large, and counts were made to determine the frequency of their occurrence. Fully bearded plants have always been found to breed true for this character (*14*). This fact supports the view that natural crossing may be the cause of the hairy plants found in several of the F_3 families.

The most convincing evidence of natural crossing comes from the F_3 generation grown from glabrous-chaffed, bearded F_2 plants of crosses between Iumillo or Kubanka with Marquis. Table III records the number of plants produced in different families as well as the number of bearded smooth, hairy, intermediate-awned, and intermediate-awned glabrous-chaffed plants. It is significant that all plants with hairy chaff had intermediate awns. This would be expected in the F_1 generation of a cross between bearded wheats and so-called awnless varieties such as Marquis or Bluestem. It is apparent that the amount of natural crossing varies in different families. For example, 196–26 produced 7 bearded, glabrous-chaffed plants and 7 intermediate-awned, hairy-chaffed plants, while family 214–35 produced 60 bearded plants.

The progeny of a few selected glabrous-chaffed, intermediate-awned F_2 plants of the cross between Marquis and durum are classified in Table IV. The parent F_2 sorts were classified as glabrous-chaffed, intermediate-awned. All such plants produced both bearded, awnless, and intermediate-awned plants in the F_3 generation. Numerous hairy-chaffed

plants were observed. None of these were bearded, all having either intermediate or very short-tipped awns like those of the Marquis parent. The evidence points to the conclusion that the hairy-chaffed plants obtained in the F_3 generation were the result of natural hybrids in the F_2 generation.

TABLE III.—*Number of hairy-chaffed intermediate-awned plants, glabrous-chaffed intermediate-awned plants, and glabrous-chaffed bearded plants in F_3 families grown from bearded glabrous-chaffed F_2 plants of crosses between Triticum durum and T. vulgare.*

Cross.	Number of plants.			
	Total.	Bearded, glabrous.	Intermediate-awned, hairy.	Intermediate-awned, glabrous.
Iumillo × Marquis:				
196–5	37	37	0	0
196–26	14	7	7	.....
196–34	131	114	16	1
198–21	66	54	9	3
199–8	48	27	19	2
199–9	74	56	17	1
225–24	47	41	6	.....
227–4	114	93	12	9
228–24	19	8	9	2
228–35	31	30	1	.....
229–21	15	15	.....	.....
232–13	37	9	26	2
232–14	51	33	10	8
Average of 26 lines	381	302	73	6
Marquis × Kubanka (C I 2094):				
208–4	10	4	6	.....
203–10	40	39	1	.....
211–23	43	40	2	1
214–35	60	60	.....	.....
217–18	35	29	5	1
218–1	36	26	10	.....
221–14	34	19	10	5
222–10	36	36	.....	.....
222–33	36	30	3	3
Average of 30 lines	495	412	54	29

TABLE IV.—*Number of hairy-chaffed plants and glabrous-chaffed plants in the F_3 families grown from intermediate-awned glabrous-chaffed F_2 plants of cross between Triticum vulgare and T. durum*

Plant No.	Number glabrous chaffed.	Number hairy-chaffed.
223–7	32	22
218–8	65	4
217–5	28	4
211–22	49	27
209–4	37	9
203–38	26	19
203–3	95	.....
214–21	39	.....

The fact that natural crossing often occurs in species crosses shows the necessity for caution in analyzing data; and unless unusual methods are employed to protect parent plants, the ancestry of the progeny can not be known with certainty.

EXPERIMENTS IN INHERITANCE OF RUST RESISTANCE

The 1918 data are considered most reliable in drawing conclusions on the inheritance of rust resistance. This is due first to the fact that all barberry bushes were removed from the immediate vicinity of the rust plot early in the spring of 1918, and second to the fact that the epidemic was induced by hand spraying with inoculations of rust spores from a known greenhouse culture of *Puccinia graminis tritici*.[1]

RUST INFECTION OF THE F_1 GENERATION COMPARED WITH THAT OF PARENTS

The epidemic in the rust plots was satisfactory, although there was but little rust in other wheat fields on University Farm.

A considerable number of F_1 crosses between resistant durum and emmer wheats and Marquis, Preston, and Pioneer were grown in the rust plot. The percentages of stemrust infection on the F_1 and parent sorts are given in Table V.

TABLE V.—*Rust notes on parental varieties and F_1 crosses between resistant and susceptible wheats, 1918*

Variety or cross.	Percentage of stemrust.	Cross.	Percentage of stemrust.
Marquis	40 to 70	Marquis×Acme (C I 5284)	70
Preston	70	Preston×Acme (C I 5284)	70
Pioneer	40	Acme×Marquis	70
Acme	10	D–4×Pioneer	40
D–4	10	Acme×Preston	70
Kubanka (C I 2094)	20	Marquis×emmer	10
Iumillo (C I 1736)	15	Emmer×Marquis	10
Emmer (Minn. 1165)	0	Emmer×Preston	15
Marquis×Iumillo (C I 1736)	40	Preston×emmer	15
Marquis×Kubanka (C I 2094)	40 to 70		

Four durum varieties were tested. The highest percentage of rust infection was 20 on Kubanka (C I 2094), while there was only 10 per cent on D–4 and Acme. On all of these durum varieties the uredinia were smaller than on the common wheats, such as Marquis and Preston, which were very susceptible. Pioneer was also susceptible, but since it matures earlier than either Marquis or Preston, the percentage of infection was lower.

[1] The details of production of the epidemic were directed by J. G. Leach, a graduate student assistant of the Pathology Division. Mr. Leach had previous experience in this work at the Tennessee Agricultural Experiment Station.

The crosses between resistant durum wheats and Marquis, Preston, and Pioneer gave similar results, the F_1 generation being rusted as badly as the susceptible common wheat parent.

Different results were obtained in the F_1 crosses of emmer (Minnesota, 1165) with Marquis and Preston. The emmer parent is practically immune from this form of *Puccinia graminis tritici* as determined both by field data and experiments in the greenhouse. Two crosses, Marquis × emmer and Preston × emmer, and reciprocals were studied. While a few small uredinia developed on the F_1 generation, all plants observed were as free from rust as the resistant durum varieties. (See Pl. 97.)

That susceptibility is a dominant character in crosses between resistant durums and susceptible common wheats and a recessive character in crosses between resistant emmer and susceptible common wheats is obvious from these results. These facts bear out the observation made in the agronomy nursery in 1916—namely, that an F_1 cross between emmer (Minnesota 1165) and Marquis was resistant, while in an adjacent row an F_1 generation of a cross between a resistant durum and Marquis was severely infected.

CORRELATION BETWEEN RUST RESISTANCE AND BOTANICAL HEAD CHARACTERS

For the purpose of determining possible interrelation between inheritance of rust resistance and other differential characters, correlated individual plant data were taken on each F_2 plant.

DURUM-COMMON CROSSES.—Notes were taken on length of head, number of spikelets, breadth of head in face and side views, average length of internode, condition of awns, and rust infection on each individual F_2 plant. These plants were then classified into six groups—namely, emmerlike with seed inclosed by the glumes, durum, near-durum, intermediate, near-common, and common.

After the elimination of the emmerlike types the principal basis for classification was the appearance of the keel of the outer glume. In durum varieties the glumes are prominently and sharply keeled, while in the common wheats the outer glumes of the spikelets are only slightly keeled. The F_1 generation of a cross between durum and common wheats was intermediate for this character (Pl. 98). This one character determined whether the plant in question approached more closely the durum or the common type. The breadth of head in face and side views, the presence or absence of the depression in the center of the outer glume, and the condition of the collar were used in making the final classification. The depression is characteristic of common wheats. In most durum wheats the collar at the base of the lower spikelet extends all around the neck of the culm, while in common wheats it extends only part way around. Since progeny of the F_2 plants were grown in the F_3 generation, mistakes in classification were rectified. The individuals finally placed

in the durum, common, and emmer groups were those which bred true. Some of the near-durums may actually belong in the durum group, but there was no attempt to rectify unimportant mistakes in these classes.

The plants were placed in four rust infection groups: group 1, practically immune, 0 to 5 per cent infection; group 2, resistant, 10 to 20 per cent infection, uredinia smaller than in the normally susceptible varieties; group 3, susceptible, 25 to 40 per cent infection; and group 4, heavily infected. These groups were based on the behavior in the F_3 generation of the progeny of each F_2 plant.

In the F_2 generation some spikes with glumes resembling common wheat were as compact as those of the durum parents or more so. These were very similar to the club wheats and were placed in the common group. Likewise, lax-headed, sharply keeled wheats were obtained which were placed in the durum group. No differentiation was made between emmer and spelt, all plants with adherent glumes being placed together. Forms were obtained, however, which closely resembled true spelt.

The results from Marquis × Iumillo and Marquis × Kubanka were similar, and the data were combined. In the final summary in Table VI each plant is classified as resistant or susceptible. The writers believe that the plants classified as resistant would not be seriously injured in a severe epidemic of this rust form. However, there is considerable variation within each group. The resistant plants belong to either class 1 or 2 for rust infection.

There were two classes of susceptible F_2 plants, those which produced all susceptible progeny in the F_3 generation and those which produced both resistant and susceptible progeny. All resistant plants bred true in the F_3 generation; at least this was the criterion used to determine whether a particular F_2 plant was really resistant.

Several conclusions can readily be drawn from Table VI. This is a tabulation of 404 F_2 plants, each of which was tested in the F_3 generation. Of these 404 plants 4, 81, and 33 bred true to the botanical head type respectively of emmer, common, and durum. All 4 emmers and 8 out of 33 durums were resistant, while 81 F_2 common segregates were all susceptible. This strongly indicates that in these crosses resistance and susceptibility are linked in transmission with the botanical head characters which differentiate durum and common wheats. The results again show that it is easy to obtain resistant durums, while it is much more difficult, if not impossible, to obtain resistant common wheats.

As has already been mentioned, both lax and dense durumlike segregates (Pl. 99) as well as compact keelless common wheats were obtained. There seems, however, to be a relation between average length of internode and the botanical classes. Thus, the average mean head densities[1] of the five groups, durum, near-durum, intermediate,

[1] Density was calculated by dividing the length of the head in millimeters by the number of spikelets less one.

near-common, and common are 3.30, 3.77, 4.08, 3.94, and 4.40, respectively. A correlation coefficient of $+0.244 \pm 0.028$ for density and head characters was obtained.

TABLE VI.—*F_2 Marquis × Iumillo (CI 1736) and Marquis × Kubanka (CI 2094)*[1]

[R=resistant to stemrust. S=susceptible to stemrust]

Density.	Durum.		Near-durum.		Intermediate.		Near-common.		Common.		Emmer.	
	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.
Mm.												
2.5	3	4	2	12	.....	9	.....	12	.....	4	.....	.....
3.0	3	8	5	28	3	20	.....	16	.....	6	1	.....
3.5	2	5	2	29	6	19	.....	14	.....	12	3	.....
4.0	.....	4	6	22	2	26	1	19	.....	16	.....	.....
4.5	.....	4	3	20	2	21	.....	14	.....	10	.....	.....
5.0	.....	.....	.....	9	1	18	.....	7	.....	18	.....	.....
5.5	.....	.....	1	5	.....	9	.....	5	.....	6	.....	.....
6.0	.....	.....	.....	3	.....	8	1	6	.....	9	.....	.....
	8	25	19	128	14	130	2	93	0	81	4	0
Ratio	1:3.1		1:6.7		1:9.3		1:46.5		0:81		4:0	

[1] The coefficient of correlation between density of head and classes for durum, near-durum, intermediate, near-common, and common is $+0.244 \pm 0.028$.

F_2 generations in which the resistant durum parent was the female are given in Table VII, a total of 632 plants being classified on the basis of the F_3 breeding test. Of these F_2 plants 100 bred true to durum habit, 47 resembled common, while 3 were emmerlike. Sixteen out of 100 durumlike plants were resistant, while only 2 out of 47 classified as common were resistant. Of the three emmerlike plants, one was susceptible and the other two were resistant. Here, again, as with the reciprocal cross, there is an indication of linkage between common wheat head characters and susceptibility to stemrust. One intermediate susceptible F_2 plant was grown in the F_3 generation, and several plants were obtained with common head characters. One of these was very resistant and vigorous (Pl. 99).

The average densities of the durum, near-durum, intermediate, near-common, and common segregates were 3.76, 3.53, 4.06, 4.38, and 4.60, respectively, although both durum and common wheats were found in the extreme dense and lax groups. The coefficient of correlation between density and head type was $+0.330 \pm 0.024$.

In order to confirm field observations, a study was made in the greenhouse of the more resistant and susceptible durum, common, and emmer segregates obtained from the durum-common crosses. For head characters of types studied see Plate 101. Seedlings of F_3 plants were

inoculated with the form of *Puccinia graminis tritici* which was used in obtaining the field epidemic. Three different tests of resistant and susceptible segregates of emmer, common, and durum F_3 lines were made. The results are given in Table VIII. (See Pl. 102.)

TABLE VII.—*F_2 Iumillo (C I 1736) × Marquis and Kubanka (C I 2094) × Marquis*[1]

[R=resistant to stemrust. S=susceptible to stemrust]

Density.	Durum.		Near-durum.		Intermediate.		Near-common.		Common.		Emmer.	
	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.	R.	S.
Mm.												
2.5	1	7	4	19	2	11	.....	2	.....	3	1	.....
3.0	8	24	11	40	.....	22	2	15	.....	2	.....	1
3.5	3	18	6	27	2	30	1	8	1	6	.....	.....
4.0	2	7	3	22	2	47	1	24	.....	6	.....	.....
4.5	.....	10	1	19	2	43	1	21	.....	7	.....	.....
5.0	1	13	1	9	.....	31	.....	16	.....	6	1	.....
5.5	.....	2	.....	2	.....	2	.....	20	1	6	.....	.....
6.0	1	3	.....	1	.....	6	.....	6	.....	9	.....	.....
	16	84	26	139	8	192	5	112	2	45	2	1
Ratio....	1:5.3		1:5.3		1:24.0		1:22.4		1:22.5		1:0.5	

[1] The coefficient of correlation between density and type as durum, near-durum, intermediate, near-common, and common is +0.330 ±0.024.

TABLE VIII.—*Comparison of resistant and susceptible F_3 lines with Marquis, Kubanka (C I 2094), and Iumillo (C I 1736)*[1]

Source.	Plant No.	Type.	Number inoculated.	Number infected.	Remarks.
Marquis	Minn. 1239	Common	10	10	Extremely susceptible.
Kubanka	C I 2094	Durum	12	10	Moderately susceptible with slight chlorosis under infected areas.
Kubanka × Marquis F_3	222–32	Emmer	18	8	Extremely resistant; uredinia minute, surrounded by sharp hypersensitive areas; 8 plants were strongly flecked.
Kubanka × Marquis F_3	222–30	...do	11	10	Highly susceptible; infection normal.
Iumillo × Marquis F_3	181–24	Common	14	12	Highly susceptible; infection normal.
Iumillo × Marquis F_3	186–13–5	...do	21	4	Infection moderate with slight chlorosis under infected areas; 7 plants were strongly flecked.
Iumillo × Marquis F_3	228–37	Durum	17	8	Moderately resistant with chlorosis under infected areas; 2 plants were distinctly flecked.
Iumillo × Marquis F_3	186–15	...do	20	19	Highly susceptible; infection normal.
Iumillo	C I 1736	...do	22	11	Slightly susceptible; 4 plants were distinctly flecked with slight chlorosis under some infected areas.

[1] The authors wish to express their thanks to M. N. Levine, Assistant Pathologist, Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, for preparing Table VIII and Plate 101 and for conducting the greenhouse experiment on which they are based.

These families were selected in the field as examples of resistant and susceptible F_3 lines. Since the inoculation results in the greenhouse corroborate the field observations, there is good reason for believing that the field observations are reliable. This greenhouse experiment shows clearly that transgressive segregation occurred. Common, durum, and emmer sorts were obtained with a higher degree of resistance than that of either of the durum parents.

These results show that, if the numbers are sufficiently large, it is possible to obtain resistant wheats with common head characters by crossing resistant durum and susceptible common varieties. In the F_2 generation, out of a total of 128 common segregates only 2 were rust-resistant, and both of these were of little commercial value. However, several resistant plants with the head characters of common wheats were obtained in the F_3 generation.

EMMER-COMMON CROSSES.—Only a few plants were available for the study of crosses between emmer and common varieties. Two different white spring emmers (Minnesota 1165 and C I 1524) were used in this study. Minnesota 1165 is a very vigorous variety which was practically immune from the form of stemrust experimented with, both in the field and in the greenhouse. C I 1524 is quite similar to Minnesota 1165, except that it occasionally produces small uredinia.

The difference between emmer and common wheat is greater than that between durum and common wheat. The shape of the head of the emmer parent, which is proportionally very narrow in face view, together with the strongly keeled glumes, differentiates it from the Marquis parent. The kernels of emmer are tightly inclosed by the glumes, and recognition is easy.

The F_1 generation of the cross between emmer and common is intermediate for the differential characters mentioned above as separating the parent sorts (Pl. 98). The keels of the F_1 generation are intermediate, but they more closely resemble those of the emmer parent. The head shape of the F_1 generation is likewise more nearly emmerlike. Fifty-six per cent of the kernels were naked and 44 per cent had adherent glumes after they were thrashed in an individual plant thrasher. The emmer parent produced 19 per cent naked kernels and 81 per cent hulled kernels. The F_1 generation (Table V) is nearly as resistant as the emmer parent. Thus, the F_1 generation more nearly resembles emmer.

Fifty F_2 plants of the cross between Marquis and emmer (Minnesota 1165) were grown in the F_3 generation. Of this number 5 plants were emmers, and 1 was a very susceptible, lax, common type. The progeny of 5 F_2 plants thrashed like common wheats in the F_3 generation, but the heads were very compact (Pl. 100). Two F_2 plants bred true to the common keel condition and segregated, producing compact, intermediate,

and lax heads. Thirty-seven produced progeny consisting of types with inclosed emmerlike kernels, intermediates for thrashing, and common plants. Of these 37 F_3 lines, 17 produced progeny of only two sorts, emmerlike for thrashing and compact keelless (Pl. 100).

It is, of course, impossible to determine the actual factors involved in this cross, because some gametes or zygotes were eliminated by sterility.

The cross in which emmer (C I 1524) was the female parent gave results similar to those obtained when emmer was used as the male parent. This is shown in Table IX. One family, 169–5, which was grown from an intermediate F_2 plant, produced emmers, intermediates, and common-headed sorts and was quite resistant (Pl. 100).

TABLE IX.—*Classification of crosses between emmer (Minnesota 1165 and C I 1524) with Marquis on the basis of rust class in the F_2 generation as determined by the F_2 and F_3 generations, and the main character differences separating emmer from common wheats as determined by the F_2 and F_3 generations*

MARQUIS × EMMER 1165

Rust class.	Emmer.	Segregating emmer to common.	With nonadherent glumes.			Total.
			Compact.	Segregating.	Common.	
1	4	9	1	1	.....	15
2	1	21	.....	.....	.....	22
3	.....	7	4	1	1	13
Total	5	37	5	2	1	50

EMMER (C I 1524) × MARQUIS

Rust class.	Emmer.	Segregating emmer to common.	With nonadherent glumes.		Total.
			Compact.	Segregating.	
1	3	3	4	.....	10
2	.....	6	2	1	9
3	.....	2	2	.....	4
Total	3	11	8	1	23

It is interesting that out of a total of 73 plants from these two crosses, 8 bred true to the emmer habit for thrashing and for head shape. Of these 8, 7 plants were put in rust class 1 while 1 was practically resistant, the progeny in the F_3 generation being placed in rust class 2. Only one lax, common plant was obtained in the F_2 generation, and this was susceptible. Several plants were obtained in the F_3 generation which were not only rust-resistant but also resembled common wheat.

These facts show that it is possible to transfer the rust resistance of emmer wheats to common wheats by crossing and subsequent selection. There is, however, an apparent partial linkage between rust resistance and the emmer head type which makes it essential to grow large numbers in the F_2 and F_3 generations.

SUMMARY

(1) Recent studies of the parasitism of the black stemrust of wheat (*16*, *18*, *21*, *24*) have shown that there are many biologic forms of *Puccinia graminis* which can be differentiated only by their action on pure line wheat hosts. This seriously complicates the breeding of wheat for rust resistance. In the light of this knowledge differences of infection of certain crosses in 1917, as compared with 1916 or 1918, show that the conflicting results may be explained logically by supposing that more than one biologic form was present in the rust nursery in 1917.

(2) Sterility is a factor which must be considered in a study of crosses between common wheats and durum or emmer varieties. Sterility was shown in three ways: (a) pollen abortion; (b) the fact that F_1 florets of durum-common crosses set nearly 50 per cent less kernels than the parent sorts, while F_1 emmer-common crosses produced about 25 per cent of barren florets; and (c) the large number of natural crosses which occurred in some F_2 plants as shown by the F_3 results.

(3) Crosses between durum and common wheats produced many different forms in the F_2 generation, such as compact keelless commons resembling club wheats, lax sharply keeled durums, both emmer and spelt, as well as types which resembled the poulard group. Lax and compact durum, common, and emmerlike forms were obtained which bred true in the F_3 generation. The segregation in the F_2 generation of emmer-common crosses was not so wide as in the durum-common cross, although both lax and compact keelless wheats which bore naked kernels, as well as lax and compact wheats with adherent-glumed kernels, were obtained.

(4) The study of inheritance of rust resistance was made in a specially prepared disease plot. Because of the conflicting results of 1916 and 1917 all barberry bushes were removed early in the spring of 1918 from the immediate vicinity of the rust plot and the epidemic was induced with a known form of rust. The data on rust infection are based on these 1918 results.

(5) The following species and varieties were used in the study: *Triticum vulgare*, varieties Preston, Marquis, and Pioneer; *Triticum durum*, varieties Acme, D-4, Kubanka (C I 2094), and Iumillo (C I 1736); *Triticum dicoccum*, White Spring emmer (Minnesota 1165 and C I 1524).

The three common wheats were susceptible, the durums were commerically resistant, Kubanka (C I 2094) being somehwat less resistant

than Iumillo (C I 1736), while Acme and D-4 were slightly more resistant than either of the other durum sorts. The emmer varieties were very resistant, Minnesota 1165 being practically immune.

(6) The F_1 generation of crosses between durum and common varieties was as susceptible as the common parent, while F_1 crosses between the practically immune emmer parents and susceptible commons were about as resistant as the durum varieties. Thus, in the cross where emmer is one parent, resistance is partially dominant, while in the durum-common cross susceptibility is completely dominant over resistance.

(7) Each F_2 plant which produced viable seed was tested in the F_3 generation for both rust infection and botanical characters. These F_3 notes were used to determine the genotypic nature of individual F_2 plants. In the crosses between durum and common in which Marquis was the female parent, 404 F_2 plants were tested in the F_3 generation and no rust-resistant common wheats were obtained. Likewise, no plants in the F_3 generation seemed especially promising for both common wheat characters and rust resistance. In the crosses in which durum was the female, one or two F_2 common-headed plants were resistant; but their progeny were worthless from a practical agronomic standpoint. In one F_3 family which was grown from a susceptible F_2 plant, a number of resistant, vigorous plants were obtained which had common head characters. There is an indication of linkage of durum or emmer characters and rust resistance, since the production of rust-resistant durums or emmers in the F_2 and F_3 generations is comparatively easy and the production of resistant common wheats much more difficult.

(8) Resistant and susceptible plants obtained either in the F_2 or F_3 generation from crosses of durum and common parents were selected. Resistant and susceptible common, emmer, and durum wheats were available for this study. Greenhouse inoculation studies with a known strain of *Puccinia graminis tritici* showed that durum, common, and emmer type plants were obtained in the F_2 or F_3 generation which were more resistant than the resistant durum parents. Thus, we have transgressive segregation for rust resistance.

(9) The number of plants available for a study of inheritance between resistant emmer parents and Marquis was not very great. In the F_3 generation several lax-headed wheats were obtained which had the head shape and naked kernels of common wheats and which were rust-resistant. This shows that rust-resistant common wheats can be obtained by crossing susceptible common varieties with resistant emmers.

(10) The mode of inheritance of rust resistance seems entirely comparable with the general Mendelian manner of inheritance of botanical and morphological characters. The technic of breeding for rust resistance is similar to that of breeding for agronomic characters.

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PLATE 97.

A.—Pollen grains of Marquis wheat.

B.—F_1 Marquis×Kubanka (C I 2094), showing sterile grains.

C.—Pollen grains of Kubanka (C I 2094).

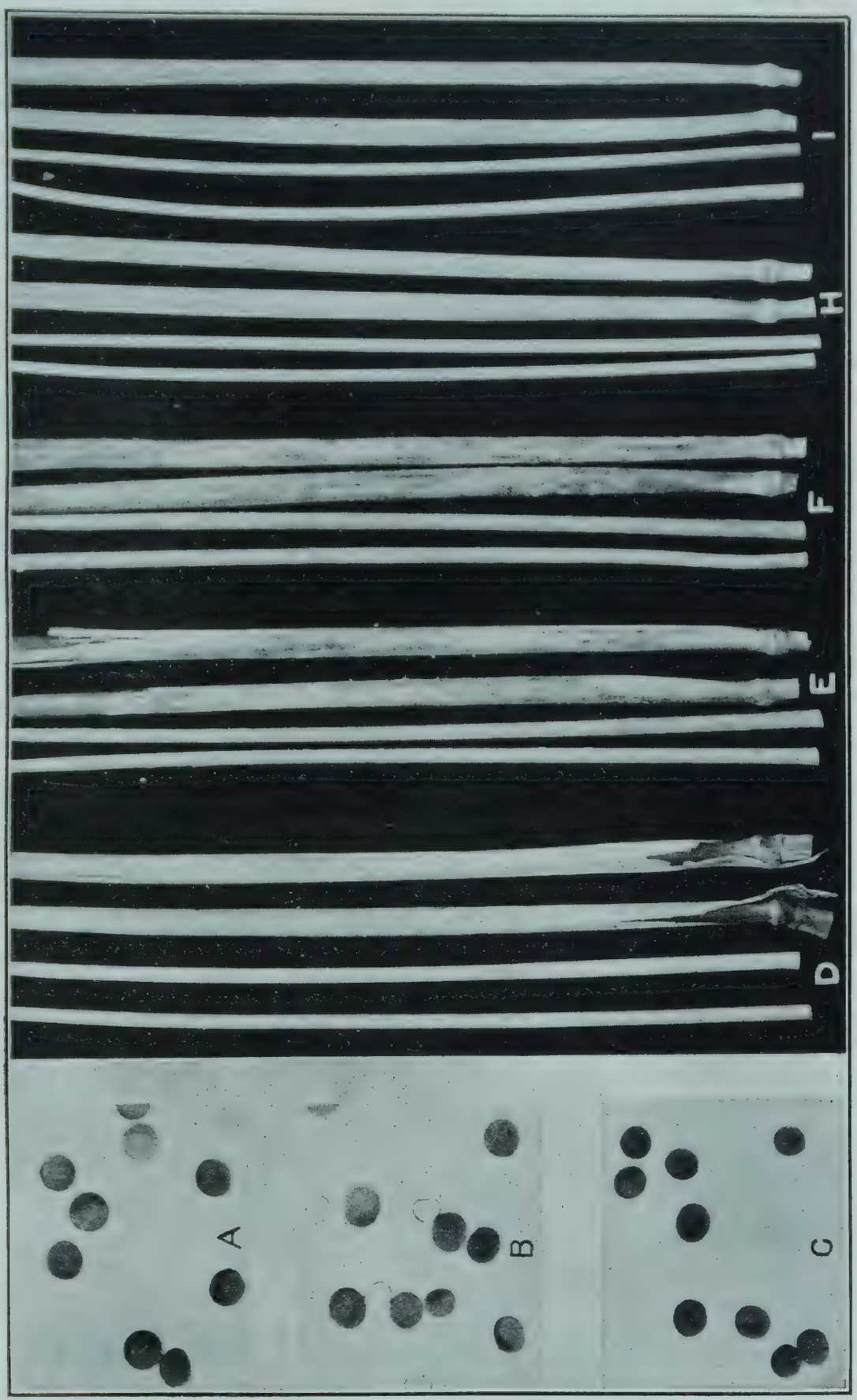
D.—Stems of Kubanka (C I 2094) grown under rust-epidemic conditions. Note absence of rust infection.

E.—F_1 Kubanka (C I 2094)×Marquis, showing normal uredinia.

F.—Marquis, the susceptible parent.

H.—F_1 emmer (Minnesota 1165)×Marquis, showing no normal uredinia.

I.—Minnesota 1165, the resistant emmer parent. Note that in the durum-common cross the F_1 generation is susceptible while in the emmer-common cross the F_1 generation is resistant.


D
E
F
H
I
A
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C

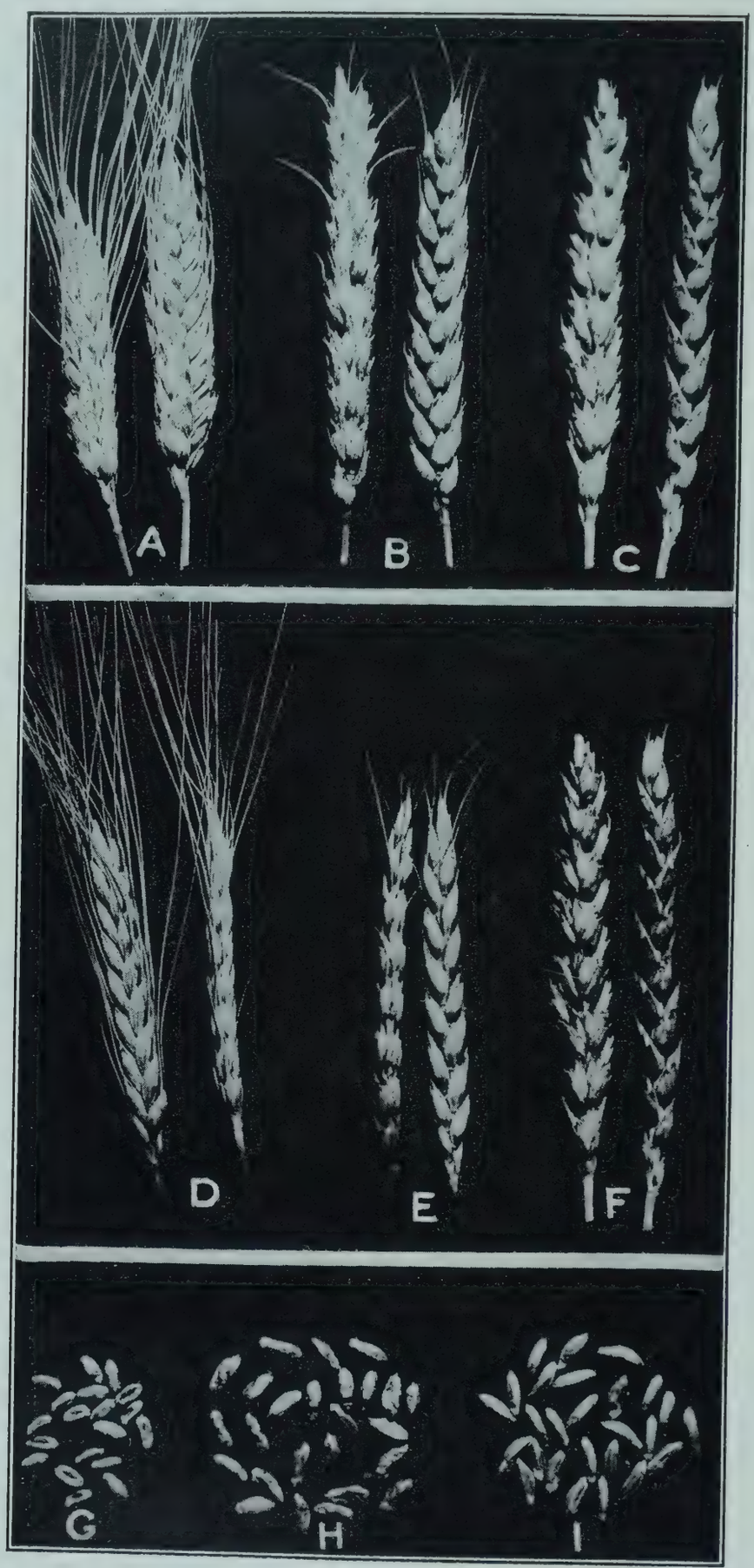
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PLATE 98.

A, B, C.—Face and side views, respectively, of heads of Iumillo (C I 1736), F_1 Iumillo × Marquis, and Marquis. The F_1 heads are intermediate in density and have tipped awns. The outer glumes are keeled, although not so strongly as Iumillo.

D, E, F.—Face and side views, respectively, of heads of emmer, Minnesota 1165, F_1 emmer × Marquis, and Marquis. The F_1 generation approaches the emmer in some head characters and has intermediate awns.

G, H, I.—Kernels of Marquis, F_1 emmer × Marquis, and emmer. The F_1 kernels are longer than Marquis, approaching those of the emmer parent in average length.

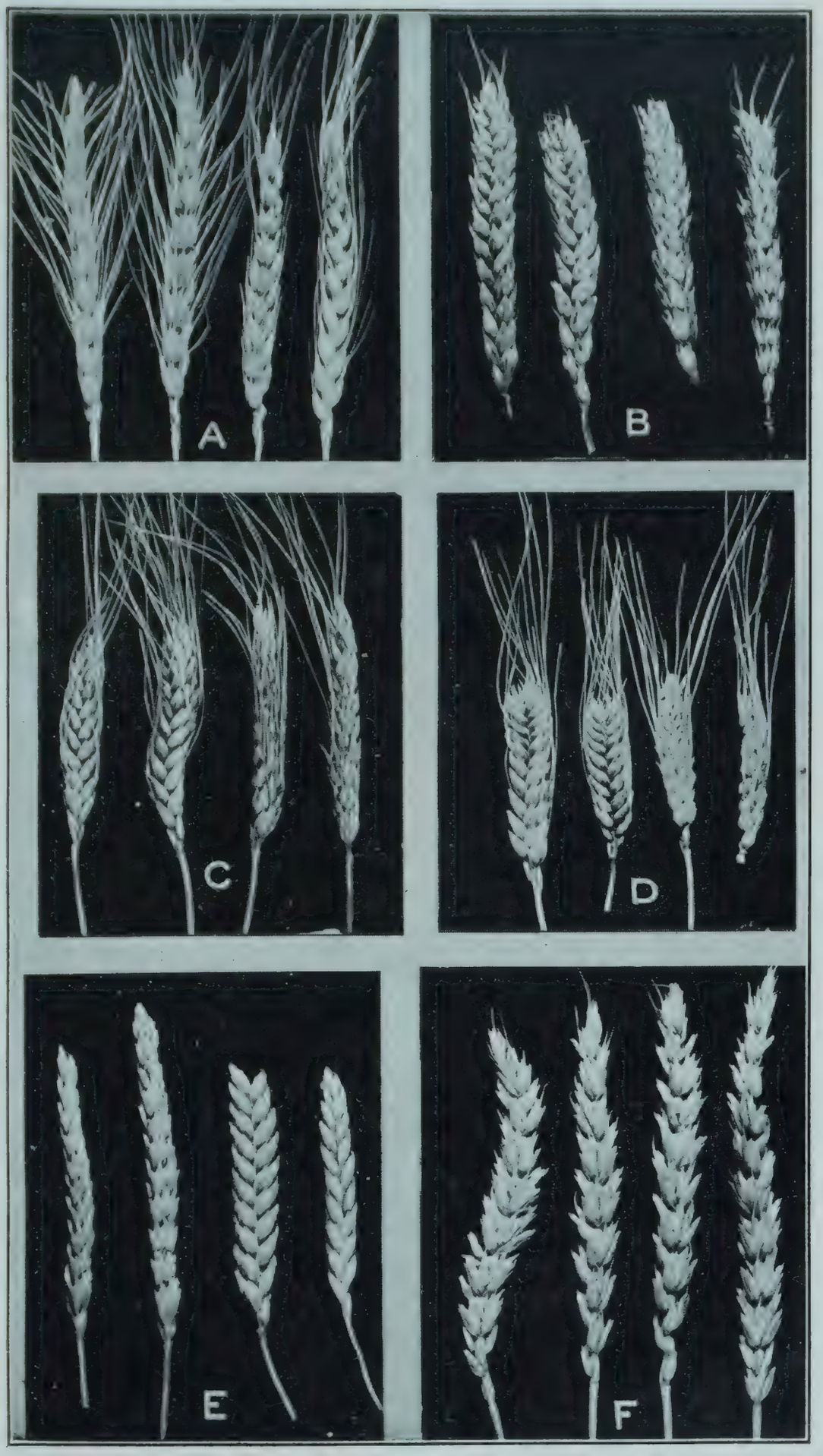
PLATE 99.

Representative heads of F_3 families of the cross between durum and Marquis.

A, B, C, D.—F_3 families which were classified as durums. Note that these represent all types of head density.

E.—Heads of an awnless F_3 emmer family.

F.—Four heads of an F_3 plant which resembles common wheat in head shape and is rust-resistant.


A
B
C
D
E
F

A
B
C
D

PLATE 100.

A.—F_3 family of a cross between emmer (Minnesota 1165), and Marquis, showing face and side view. This family proved rust-resistant and was also pure for keelless, compact heads and thrashed like common wheat.

B.—Heads of an F_3 family which resembled common wheat. It was rust-susceptible.

C.—Heads of different plants of an F_3 family of a cross between emmer (C I 1524) and Marquis. The plants varied from emmerlike and intermediate forms to those resembling common wheat as shown at the left. This family bred true for rust resistance.

D.—Represents a very frequent sort of segregation obtained in the F_3 generation. Many families gave only emmerlike and keelless, compact headed sorts which thrashed like common wheat.

PLATE 101.

Heads of resistant and susceptible wheat obtained in the F_3 generation from the cross between Marquis and durum:

A.—Head representing resistant emmer type F_3 family 222–32, Kubanka × Marquis.

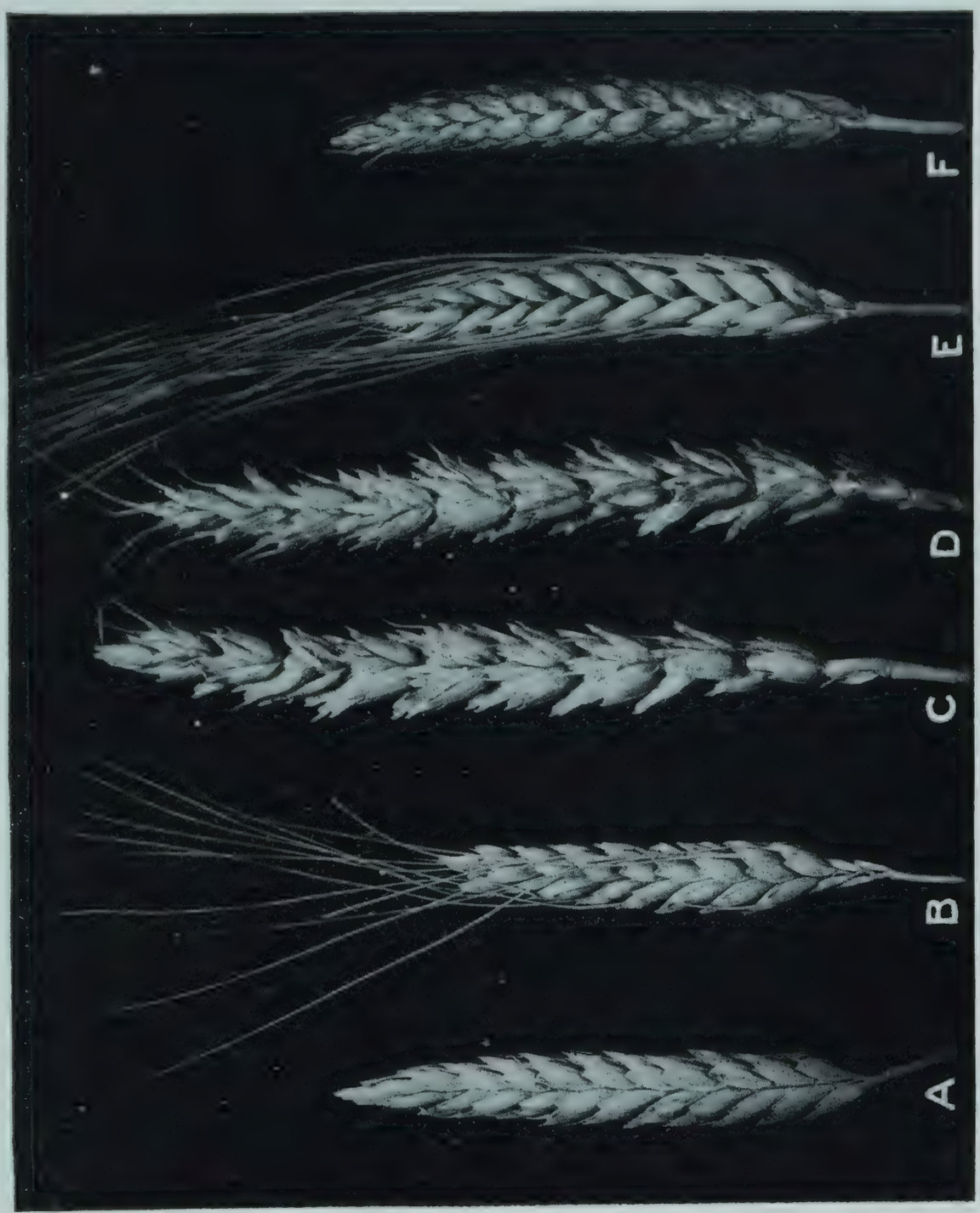
B.—Head representing susceptible emmer F_3 family 222–30, Kubanka × Marquis.

C.—Susceptible common F_3 family 181–24, Iumillo × Marquis.

D.—Resistant individual plant 186–13–5 which was obtained in the F_3 generation of the cross between Iumillo × Marquis.

E.—Resistant durum F_3 family 228–37, Iumillo × Marquis.

F.—Susceptible durum F_3 family 186–15, Marquis × Iumillo.


A
B
C
D
E
F

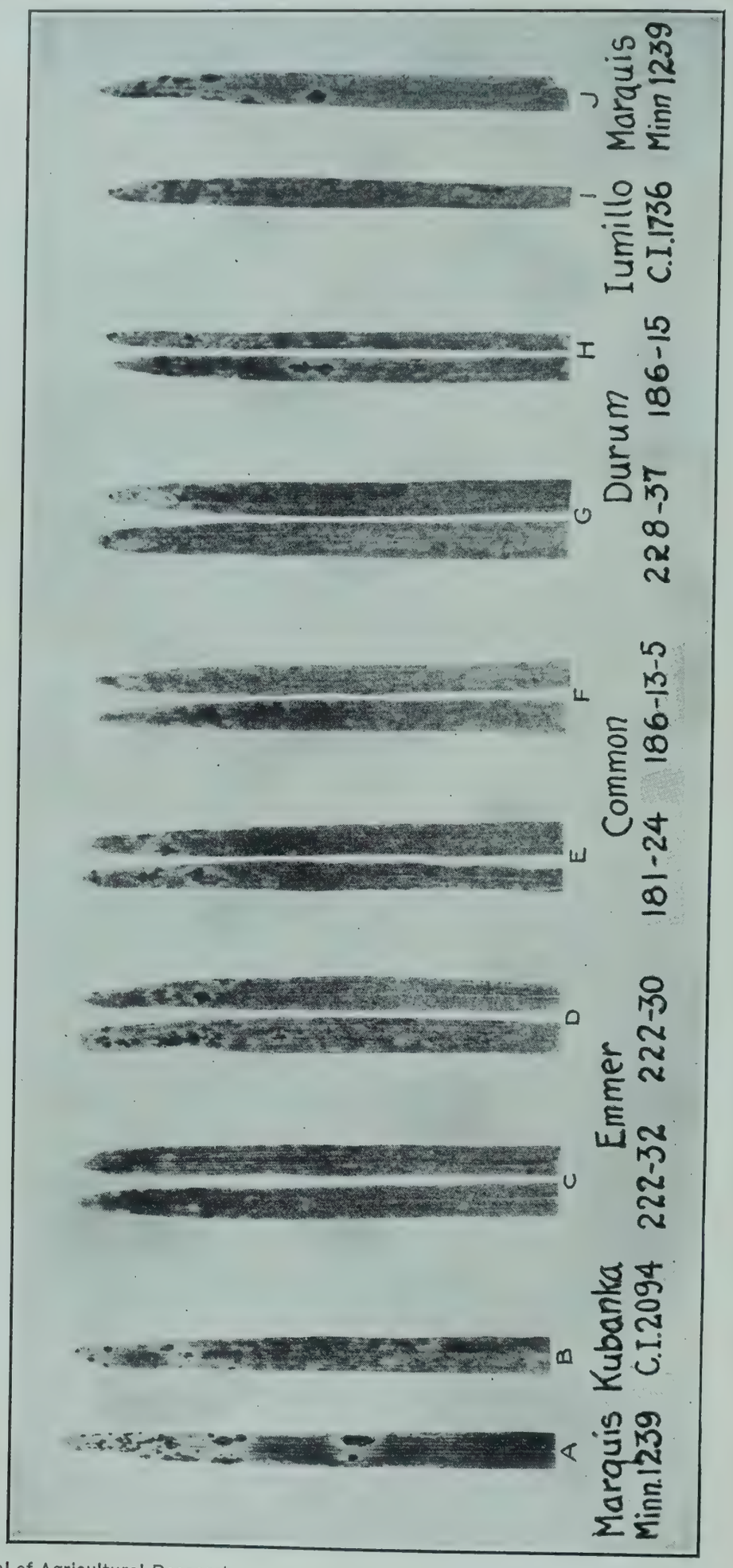

Marquis Minn.1239
A
Kubanka C.I.2094
B
Emmer 222-32
C
222-30
D
Common 181-24
E
186-13-5
F
Durum 228-37
G
186-15
H
Iumillo C.I.1736
I
Marquis Minn 1239
J

PLATE 102.

Greenhouse experiment:

A.—Marquis, single blade, showing extreme susceptibility.

B.—Kubanka (C I 2094), single blade; moderately susceptible with slight chlorosis.

C.—Kubanka × Marquis (222–32 F_3 emmerlike family); extremely resistant; uredinia minute surrounded by hypersensitive areas, or flecks.

D.—Kubanka × Marquis (222–30 F_3 emmerlike family); very susceptible.

E.—Iumillo × Marquis (181–24 F_3 common family); very susceptible.

F.—Iumillo × Marquis (186–13–5, an individual common plant of F_3 family 186–13); moderately resistant with infected areas chlorotic.

G.—Iumillo × Marquis (228–37 F_3 durum family); moderately resistant with infected areas chlorotic.

H.—Iumillo × Marquis (186–15 F_3 durum family); fairly susceptible.

I.—Iumillo (C I 1736), single blade; slightly susceptible.

J.—Marquis (Minnesota 1239), single blade; highly susceptible.

The rust form used in the greenhouse experiment was the same as that used for the 1918 field epidemic.

LINE-SELECTION WORK WITH POTATOES

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The data and discussions presented here have to do with the subject of potato-seed improvement through tuber selection. As such it deals with the improvement of existing varieties and may be contrasted with another type of potato breeding which, through the mediums of fertilization, production of seed, and growing of seedlings, aims at the origin of new varieties.

In the language of the plant breeder potato varieties are termed clons or clonal varieties. To him they differ from varieties of wheat, barley, or corn in that they are propagated from vegetative parts. Sexual reproduction or the use of seeds is resorted to only as a means of originating new varieties, not as a means of perpetuating existing ones. Varieties of wheat, barley, or corn reproduce true from seed, while clonal varieties do not. In other words, if we plant pure seed of yellow corn or blue barley, we harvest yellow corn or blue barley, but if we should plant seeds of red apples or red potatoes it is very doubtful if we should harvest either red apples or red potatoes. Few, if any, will doubt the value of potato-breeding work which has for its object the origin of new varieties from seed. Most of our potato varieties have originated as seedlings, either chance seedlings or those resulting from carefully planned breeding work. This phase of potato breeding is still attracting the attention of both scientific and amateur plant breeders, and new seedlings are constantly being introduced for trial. Some of these are real additions to potato culture, and others prove of only local and passing interest.

The improvement of clonal varieties through bud selection has been the subject of much discussion and the basis for much experimental study. In propagation, the horticulturist deals largely with clons or varieties which must be perpetuated by transplanting vegetative parts. Fruit trees, small fruits, many ornamental plants, nut trees, bulbous and tuberous plants, and many flowers, particularly greenhouse specialties, fall in this class. This line of plant breeding is of just as vital importance as the other which aims at improvement through crossing and hybridization and the growing of new seedlings. Potatoes have been the subject of much study along this line, the work of East,[1] Eustace,[2]

[1] EAST, Edward M. A STUDY OF THE FACTORS INFLUENCING THE IMPROVEMENT OF THE POTATO. Ill. Agr. Exp. Sta. Bul. 127, p. 375–456, 10 fig. 1908. Bibliography, p. 450–456.

——— THE TRANSMISSION OF VARIATIONS IN THE POTATO IN ASEXUAL REPRODUCTION. *In* Conn. Agr. Exp. Sta. Rpt. 1909/10, p. 119–160, 5 pl. 1910.

[2] EUSTACE, H. J. AN EXPERIMENT ON THE SELECTION OF "SEED" POTATOES: PRODUCTIVE VS. UNPRODUCTIVE HILLS. *In* Proc. Soc. Hort. Sci., 1903/04, p. 60–62. 1905.

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Waid,[1] and Zavitz[2] being the most important of that reported in America. It is safe to say, however, that the work done so far has not by any means cleared up the subject of selection within clonal varieties. At present we can not say that we have a clear vision of the possibilities or the limitations along this line of plant breeding. Since plants within clonal varieties vary, we have assumed that there is opportunity for improvement through selection just as in varieties that are propagated from seed. But to what extent we can make use of selection to perpetuate desirable variations within the clon and in this way improve these varieties is still a question.

The plant breeder recognizes in plants three types of variations: (1) fluctuations or modifications, (2) segregations or combinations, and (3) mutations. Fluctuations are such variations as appear as a result of variable environmental conditions and are by many considered nonheritable or nontransmittable from one generation to another, regardless of whether perpetuation is through seeds or vegetative parts. In other words, if we accept this theory of the nonheritability of fluctuations due to environment we can not expect to increase the average vigor of a potato variety by selecting seed tubers from especially vigorous hills so long as the variation in vigor might be attributed to environmental conditions. Segregations are heritable differences resulting from segregation and recombination of hereditary units. This type of variation appears within the population of new hybrids and crosses perpetuated by seeds rather than by vegetative multiplication. Among potatoes we could expect such variations to appear only among seedlings, and for this reason segregation can not be considered among the possibilities for improving potato varieties which are perpetuated vegetatively. Mutations are heritable variations which do not depend upon segregation and recombination. Mutations are supposed to be much rarer than the other variations mentioned. Among horticultural plants many clonal varieties have arisen in this way and have for many years been perpetuated true to type through vegetative multiplication. An excellent example of a mutant among potatoes is the. Pearl, which originated as a mutation, or in common language, as a bud sport from the Blue Victor. This has occurred not only once but several times. In our own Blue Victor seed plot of 1918 there appeared such a variation. This mutant was a perfect Blue Victor with the exception that it was white instead of blue in color. In other words, it was a perfect Pearl. In this seed plot, seed pieces from each tuber were planted in consecutive hills. The hills were thinned to single stems, and just one

[1] GREEN, W. J., and WAID, C. W. POTATO INVESTIGATIONS. SPRAYING AND SEED SELECTION EXPERIMENTS; VARIETY TESTS. Ohio Agr. Exp. Sta. Bul. 174, p. 251–289, 18 fig. 1906.

WAID, C. W. RESULTS OF HILL SELECTION OF SEED POTATOES. *In* Amer. Breeders' Assoc. Rpt., v. 3, p. 191–199. 1907.

[2] ZAVITZ, C. A. [REPORT OF THE DEPARTMENT OF FIELD HUSBANDRY.] *In* 31st Ann. Rpt. Ontario Agr. Exp. Col. and Exp. Farm, 1905, p. 165–220. 1905.

plant appeared with white potatoes. This means that one eye from a typical Blue Victor tuber produced a plant which bore white potatoes while all other eyes from the same tuber produced plants with blue potatoes true to type. This hill of white potatoes will, if planted, give plants bearing only white potatoes, for these simple bud sports or simple vegetative mutants may be perpetuated by propagation from vegetative parts. Here, then, we have an excellent example of how new varieties appear by mutation, but apparently such bud sports do not appear frequently.

If we purpose to champion the cause of selection within potato clons we must either show that high-yielding mutants, less striking than the one just mentioned and possibly for this reason more often unobserved, frequently appear within the clon and form the basis for selection, or we must break down, so far as clonal varieties are concerned, the theory that all fluctuations, or modifications are nonheritable. The greater part of the data here presented is the result of work begun with the intent of throwing light upon the first question. Experiments are also under way bearing upon the heritability of fluctuations, but as yet the data are not sufficient to warrant publication.

No one, I think, will doubt the value of certain lines of potato seed-selection work. For instance, there is abundant evidence to show that under anything like favorable environmental conditions the yielding power of a variety may be maintained by careful selection. In other words, a system of seed-tuber production which aims at the annual elimination of diseased or degenerate hills will, except under the most unfavorable environmental conditions, maintain a high-yielding population of any variety. But aside from the elimination of these weak hills we may question whether any practical results will come from further effort. In this case we are eliminating the hills that are below the average in vigor, the loss of vigor being due to attacks of disease or to degeneration. A very satisfactory method of procedure in such selection efforts is well outlined in Circular 73 of this Station.[1] The extent to which yields are increased by such selection is largely determined by the stock started with, its susceptibility to disease, and the tendency of the particular variety to degeneration under existing climatic and soil conditions. Starting with a variety population containing a large percentage of degenerate or diseased plants, proper selection will bring about a marked increase in yield. In growing a variety that has degenerrate tendencies under certain environmental conditions, such a system of selection will be found very helpful in maintaining the yielding power of the variety. For the purpose of illustration, some examples may be cited. Russet Burbank, as it has been grown at Bozeman, is a very stable variety. Very few diseased hills appear in the plots, and very

[1] WHIPPLE, O. B., A SEED PLOT METHOD OF POTATO IMPROVEMENT. Mont. Agr. Exp. Sta. Circ. 73, p. 71–73. 1917.

few degenerate plants are found. Irish Cobbler and Early Triumph have behaved in just the opposite way, at least so far as degeneration is concerned. Within the last two varieties, as grown under our conditions, intelligent selection will give surprising results. With the Russet Burbank, profitable increase in yield might result from selection, but the improvement would be in no way spectacular. This type of selection work aims at increased production through the elimination of plants yielding below the average of the population.

The first work in line selection was undertaken in 1913 with the selection from the crop of that year of a few high-yielding hills of Russet Burbank (hills 201 to 206) and Rural New Yorker (hills 207 to 212). These have now been tested for five years, and a summary of the results is given in Table I. While these data do not represent a very large amount of experimental evidence, I believe that the results indicate what can be expected when effort is made to isolate high-yielding clonal lines by hill selection and maintain them by mass selection based upon tuber characteristics. Every effort was made to eliminate experimental errors. Seed pieces were dropped 15 inches apart in rows 3 feet 9 inches apart. Single-row plots were used with outside or guard rows in every case. In 1914, these plots were necessarily small. In 1915, 1/40-acre plots were used, and since 1915 plots of approximately 1/20-acre have been grown. No special effort has been made to control the size of the seed piece; but in 1914, 1915, and 1916 the plots were thinned to single-stemmed hills. This method gives promise of being as reliable as one based on the planting of uniform-sized seed pieces, for size of seed piece appears to influence yield only in so far as it is correlated with the number of stems produced in the hill. In other years the size of seed pieces could not have varied greatly, since the plan of cutting tubers of certain sizes to so many seed pieces was followed, without reference to number of eyes. The hills selected in 1913 were single-stemmed hills and were chosen on yield and tuber characteristics entirely. Of a large number of hills dug with a fork, those were selected which gave the greatest weight of tubers of good form. Tubers considered of good form were those long for the variety, full and rounded at both ends, and oval rather than round in cross section. In choosing seed by mass selection, the same form characteristics were considered; and the seed was picked after the digger. The seed for control plots was chosen by mass selection from the population of the variety from which the hills originally came, selection being based upon the same tuber characteristics. Single-plot tests were employed.

In Table I, I wish to call attention not so much to the 5-year performance record of the hill lines as to the very marked variation between their yields in 1914 and 1915 when compared with the control plots. If we take the 5-year average as a reliable indicator, some of these lines are apparently better yielders than others. I believe, however, that an-

other 5 years added to these performance records will go a long way toward blotting out these apparent differences. It will be noted that all these hills gave a very large increase over the control plots in 1914. But the interesting feature of the records is that following mass selection in 1914, the average yield of these lines immediately falls, in 1915, to the level of that of the control plot. In this connection it should be borne in mind that these two varieties are very stable under conditions at the Station and that neither has shown any serious tendency toward degeneration. The increased production in 1914 can not be accounted for on the theory that degenerate or weak hills were common in the control plots in 1914, nor can the decrease in yield in 1915 be accounted for on the theory that mass selection introduced into these lines degenerate types which tended to lower the yield of 1915. I believe the data clearly indicate that hill selection brings only temporary increases in yield and that such selection does not isolate high-yielding lines which may be maintained as high-yielding population by mass selection based on tuber characteristics alone.

TABLE I.—*Five-year summary of yields of marketable tubers per acre from hills selected in 1913*

Hill No.	1914	1915	1916	1917	1918	5-year average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
201	14,764	13,350	8,552	23,580	10,849	14,219
202	19,446	12,461	7,456	20,537	13,497	14,579
203	18,409	12,543	8,880	23,394	13,660	15,377
204	19,924	10,930	8,515	23,464	13,033	15,173
205	18,207	12,947	7,572	18,724	10,756	13,641
206	13,839	11,898	7,744	18,353	.....	12,958
Average	17,431	12,354	8,119	21,342	12,359	14,341
Control	11,836	12,947	8,766	19,143	17,424	14,023
207	14,157	11,823	7,509	21,675	14,961	14,025
208	12,251	14,278	5,406	19,514	16,425	13,574
209	18,513	9,873	6,969	22,511	20,490	15,671
210	17,936	8,566	6,218	20,932	15,007	13,731
211	17,616	8,826	.....	16,090	21,141	15,918
212	18,315	7,700	.....	20,328	11,685	14,507
Average	16,464	10,177	6,525	20,175	16,618	14,571
Control	10,257	9,961	6,069	20,165	17,214	12,733

In 1916 work of similar nature was undertaken upon a more extended scale. With the selection of 108 tuber units each of Green Mountain, Rural New Yorker, and Early Six Weeks, 324 tuber lines were established, which have now been carried through three seasons. Eight of these lines were thrown out from the Early Six Weeks as variety mixtures, most of the 8 being Early Rose, so the summary on this variety covers only 100 tuber lines. Rural New Yorker has been previously referred to as quite

stable. Green Mountain, as grown at Bozeman, has rather strong degenerate tendencies, but Early Six Weeks would be classed as almost as stable as Rural New Yorker, since no rapid decline in yield followed selection based upon tuber characteristics. Since in this work every effort has been made to overcome the possibility of error, a discussion of methods will be in order.

Tuber units were selected from the bin in the spring of 1916. In each variety these tubers were cut to a uniform weight by slicing off the stem end. The Green Mountain tubers were cut to 7 ounces, the Rural New Yorker to 8¾ ounces, and the Early Six Weeks to 6½ ounces. The remaining portion of the tuber was then quartered lengthwise. Since 1916 seed pieces have been cut with a special cutter which cuts a seed piece approximately hemisperical in shape, 1¼ inches across the face and ¾ inch deep. Such seed pieces weigh approximately ⅓ ounce, or about 11 gm. Because of variation in depth of eyes, these seed pieces will differ somewhat in weight, the maximum variation within a variety usually not exceeding 2 gm. and in many cases not exceeding 1 gm. Groups of 20 seed pieces seldom show variation of over 15 gm. While these seed pieces may appear small, they have apparently given just as strong plants as seed pieces cut in the usual manner and weighing 1½ ounces. Seed pieces have been planted by hand and covered to a uniform depth of 3 inches. Single-plot tests have been used entirely. Such tests carried on over a series of years should give just as reliable results as duplicate or triplicate tests conducted for a shorter period. Duplicating plots complicates the work of seed selection. It is not safe to select seed from any one plot to continue the line the following season, and it is difficult to select a small composite sample from two or three plots. It is for this reason that the single-plot test was decided upon.

The 1916 plots consisted of 4 hills, and the 1917 and 1918 plots of 20 hills. The latter is the standard-sized plot adopted here for this work. The selections from each variety are arranged in a group with from 9 to 12 plots in a row and from 9 to 12 rows. There is no space between plots in the rows. The control plot consists of a single row near the center of the group running the length of the group of plots. Hills are planted 15 inches apart in rows 3 feet 9 inches apart. Seed is chosen from the plots before the tubers are assembled, and in this way it is secured from different portions of the plot. To illustrate, from a standard-sized plot 5 seed tubers are selected. Four seed pieces from each tuber are planted the following season in adjacent hills, and when this crop is harvested, effort is made to select one seed tuber from each group of four hills, or from each unit, as they are called later. The plots receive rather deep cultivation, are well ridged, and are commonly irrigated once. At any rate they all receive the same cultivation and irrigation. All hills are thinned to single stems as soon as the vines are strong enough to pull, or from five to six weeks after planting.

Since these small seed pieces give an average of only about 1½ stems per hill, the thinning is not a very great task. Careful records are kept of the number and weight of marketable tubers and culls. Yields are computed upon the basis of a perfect stand. Naturally this favors the plot with an imperfect stand, for a missing hill tends to raise the yield of adjacent hills. Stand records are kept, showing the position of missing hills. As yet there is no basis upon which to apply such records in correcting yields, but I hope to make use of these later. Careful notes are also kept upon vine characteristics. We are particularly interested in those that indicate degeneration. Three general types of vines—vigorous, semi-curlydwarf or with curlydwarf tendencies, and curlydwarfs—are recognized.

The results of three seasons' work upon this project are presented here, not with the idea of proving the presence or the absence of high-yielding tuber lines within these 316 selections but rather for the purpose of calling attention to the difficulty of interpreting these performance records. If such a method of seed improvement is to be of real and practical value, especially in the hands of the average potato grower, it would seem that a 3-year test should give rather definite and dependable results. If the process is to be a longer one than this, then the method should be proposed for the potato specialist rather than for the rank and file of potato growers.

GREEN MOUNTAIN TUBER LINES 300 TO 408

In variety tests at this Station, the Green Mountain types have on an average given the highest yields of all varieties grown. Varieties belonging to this group have, however, varied rather widely in yields. They are more susceptible to scab, more inclined to degeneration, and produce tubers less desirable as to commercial form than the Rural New Yorker; but withal the type is a very promising main-crop commercial potato.

In Table II will be found the 3-year performance records of the 108 Green Mountain lines, expressed in yields of pounds per acre. Of the three groups of tuber lines, these have given the most noticeable variations in yields.

Line 332 ranks first with a 3-year average yield of 27,849 pounds per acre, while line 344 has a 3-year average of 3,841 pounds. When ranked on 3-year average tuber production by weight, the 20 highest-yielding lines assembled in the last column of Table III have given an average yield of 25,000 pounds per acre, while the 20 lowest-ranking, appearing in the last column of Table IV, have averaged 12,083 pounds.

In Tables III and IV it will be noticed that only a few of the lines appear as consistent high or low yielders. Several numbers will be found in both tables, showing that lines have swung from one extreme to the other.

TABLE II.—*Three-year summary of yields of marketable tubers per acre from 108 Green Mountain tuber lines*

Tuber line No.	1916	1917	1918	3-year average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
300	10,453	20,442	26,017	18,970
301	10,453	23,230	16,261	16,648
302	11,034	22,300	19,071	17,468
304	12,776	26,946	14,247	17,989
305	13,357	22,553	15,486	17,132
306	15,680	30,199	29,340	25,073
307	11,615	21,836	14,402	15,951
308	6,969	27,411	11,873	15,417
309	12,776	26,017	11,615	16,802
310	13,938	20,442	26,482	20,287
311	11,615	23,230	21,603	18,816
312	12,195	19,513	13,938	15,215
313	9,872	25,553	13,705	16,376
314	11,034	26,482	10,840	16,118
315	11,615	31,128	16,626	19,789
316	15,608	24,623	11,736	17,322
317	15,099	33,915	23,472	24,162
318	13,938	30,199	10,269	18,135
319	13,938	17,190	21,371	17,499
320	15,099	22,765	30,663	22,842
321	9,292	22,300	15,099	15,563
322	11,615	26,017	16,626	18,086
323	13,938	32,057	13,938	19,977
324	15,680	37,168	21,836	24,894
325	11,615	29,734	19,164	20,171
326	11,034	34,380	20,907	22,107
327	10,453	37,632	14,867	20,984
328	10,453	15,796	10,453	12,234
329	10,453	28,340	13,936	17,576
330	9,292	27,876	30,318	22,495
331	7,549	26,946	23,230	19,241
332	15,099	39,026	29,424	27,849
333	14,518	37,632	25,320	25,823
334	10,453	24,623	10,221	15,099
335	11,615	33,915	16,028	20,519
336	11,034	36,238	14,670	20,647
337	12,195	15,331	7,665	11,730
338	19,164	29,269	22,738	23,723
339	12,195	19,513	10,513	14,073
340	13,357	28,340	24,262	21,986
341	5,807	29,269	8,595	14,557
342	6,969	23,230	11,615	13,938
343	12,195	35,309	26,249	24,584
344	1,742	9,292	489	3,841
345	15,680	14,402	1,366	10,482
346	9,292	10,685	8,001	9,326
347	10,453	17,654	6,968	11,691
348	14,518	18,584	30,715	21,272
349	8,130	23,230	12,776	14,712
350	10,453	24,159	15,796	16,802
351	13,938	27,875	15,099	18,970
352	14,518	28,495	19,048	20,687
353	12,195	26,946	20,674	19,938
354	17,422	33,451	31,128	27,333
355	14,518	22,765	20,293	19,192
356	10,453	19,048	8,362	12,621
357	12,776	18,584	18,351	16,570
358	10,453	23,694	11,751	15,299
359	11,034	27,876	13,936	17,615

TABLE II.—*Three-year summary of yields of marketable tubers per acre from 108 Green Mountain tuber lines*—Continued

Tuber line No.	1916	1917	1918	3-year average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
360	13,936	25,553	20,674	20,054
361	11,615	22,300	26,714	20,202
362	11,615	31,592	29,966	24,399
363	12,195	32,766	30,807	25,251
364	7,549	21,836	9,292	12,896
365	10,453	23,230	11,150	14,944
366	9,292	34,380	14,670	19,447
367	8,130	27,876	19,745	18,583
368	11,034	23,230	9,808	14,690
369	9,292	22,300	13,692	15,094
370	10,453	16,261	7,824	11,512
371	11,034	31,128	17,604	19,922
372	13,357	30,321	31,296	24,991
373	15,099	34,845	24,205	24,716
374	6,388	20,442	5,342	10,724
375	11,613	29,343	11,980	17,645
376	9,872	33,915	30,073	24,620
377	8,516	33,849	22,997	21,787
378	6,969	27,411	19,513	17,964
379	10,453	22,765	15,099	16,105
380	12,195	25,553	13,274	17,007
381	8,130	21,029	7,433	12,197
382	13,938	27,876	19,100	20,304
383	12,195	35,309	22,983	23,495
384	8,711	26,017	16,261	16,996
385	5,807	21,371	4,181	10,453
386	12,776	32,522	13,008	19,435
387	14,518	23,230	12,079	16,609
388	16,261	38,581	27,873	27,571
389	9,872	24,941	12,714	15,842
390	15,099	32,522	28,362	25,327
391	16,259	30,663	32,986	26,636
392	12,776	24,623	12,079	16,492
393	13,357	25,088	13,241	17,228
394	7,549	34,380	20,674	20,867
395	5,807	34,722	12,079	17,536
396	7,549	36,238	25,088	22,958
397	10,065	21,836	19,513	17,138
398	8,130	30,663	28,572	22,455
399	9,872	29,269	22,997	20,712
400	8,130	28,590	29,269	21,996
401	9,292	23,694	11,873	14,953
402	7,549	20,907	6,504	11,653
403	6,388	26,017	13,203	15,202
404	15,099	34,845	22,713	24,219
405	11,615	30,663	15,159	19,145
406	12,776	30,199	22,005	21,660
407	11,613	23,694	18,584	17,963
408	9,291	19,298	11,615	13,401
Yearly average	11,335	26,595	17,493	18,474

TABLE III.—*Twenty highest annual rankings and 3-year average rankings from 108 Green Mountain tuber lines*[a]

1918		1917		1916		3-year average.	
Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
**391	32,986	332	39,026	*388	19,165	***332	27,849
*372	31,296	388	38,582	354	17,423	***388	27,571
***354	31,128	333	37,633	388	16,261	***354	27,333
*363	30,807	*327	37,633	391	16,259	**391	26,636
**348	30,715	**324	37,168	306	15,680	***333	25,823
**320	30,663	*396	36,239	*316	15,680	**390	25,327
*330	30,318	*336	36,239	*345	15,680	*363	25,256
**376	30,073	343	35,310	324	15,680	**306	25,073
*362	29,966	*383	35,310	317	15,099	*372	24,991
***332	29,424	**404	34,845	373	15,099	**324	24,894
**306	29,340	**373	34,845	404	15,099	**373	24,716
*400	29,269	*395	34,723	332	15,099	**376	24,620
*398	28,572	*394	34,380	390	15,099	**343	24,584
**390	28,362	*366	34,380	320	15,099	*362	24,391
***388	27,873	*326	34,380	333	14,519	**404	24,219
*361	26,714	376	33,916	*387	14,519	**317	24,162
**310	26,482	*335	33,916	*355	14,519	*338	23,723
**343	26,249	**317	33,916	*352	14,519	*383	23,495
*300	26,017	*377	33,849	348	14,519	**320	22,842
***333	25,320	354	33,451	310	13,938	*330	22,495
				*318	13,938		
				*319	13,938		
				*323	13,938		
				*351	13,938		
				*382	13,938		

[a] The number of stars indicates how many times the line has appeared among the 20 highest-yielding lines. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. Four lines appear three times, 12 appear twice, and 29 appear only once.

TABLE IV.—*Twenty lowest annual rankings and 3-year average rankings from 108 Green Mountain tuber lines*[a]

1918		1917		1916		3-year average.	
Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
**344	489	344	9,292	341	5,808	**344	3,841
**345	1,368	346	10,686	385	5,808	**346	9,326
***385	4,181	345	14,403	*395	5,808	***385	10,453
***374	5,342	337	15,332	374	6,388	**345	10,482
***402	6,504	328	15,796	*403	6,388	***374	10,724
**347	6,968	*330	16,261	*378	6,969	*370	11,512
***381	7,433	*319	17,190	*342	6,969	***402	11,653
**337	7,665	347	17,655	*308	6,969	**347	11,691
*370	7,824	*348	18,584	402	7,550	**337	11,730
**346	8,001	*357	18,584	364	7,550	***381	12,197
**356	8,362	356	19,049	*394	7,550	**328	12,234
**341	8,595	*408	19,299	*396	7,550	**356	12,621
**364	9,292	339	19,513	*331	7,550	**364	12,892
*368	9,808	*312	19,513	*349	8,131	*408	13,401
*334	10,221	*310	20,442	*367	8,131	*342	13,938
*318	10,269	374	20,442	*398	8,131	**339	14,073
**328	10,453	*300	20,442	*400	8,131	**341	14,557
**339	10,513	402	20,907	381	8,131	*368	14,690
*314	10,840	381	21,029	*377	8,517	*349	14,712
*365	11,150	385	21,372	*384	8,711	*365	14,944

[a] The number of stars indicates how many years the line has appeared among the 20 lowest-yielding lines. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. Four appear three times, 10 appear twice, and 28 appear only once.

If with these records before us we attempt to point out apparently promising lines, we must base our judgment either upon the frequency with which the line appears among the high-yielding lines or upon its performance as indicated by the 3-year average. The following 1918 field notes are upon the lines that have appeared at least two out of the three seasons among the 20 highest or that rank with the 20 highest according to the 3-year average.

LINE NO.	REMARKS.
332.	First two units lacking in vigor but others vigorous. Variations may be due to soil.
388.	Fourth unit a typical semi-curlydwarf.
354.	First unit semi-curlydwarf.
391.	A good vigorous type.
333.	A good vigorous type.
390.	A good vigorous type.
363.	A good vigorous type; third unit inclined to semi-curlydwarf.
306.	First unit curlydwarf; others fairly vigorous.
372.	A good vigorous type.
324.	A fairly good type; a few weak plants, but these may possibly be due to soil.
373.	Variable as to vigor; some plants with curlydwarf tendencies, though all are fairly vigorous.
343.	A good vigorous type with exception of first unit.
362.	A good vigorous type.
404.	A good vigorous type.
317.	A good vigorous type.
338.	A good vigorous type.
383.	A very good type; some variation as to vigor, but this may possibly be due to soil.
320.	Vigorous with exception of third unit, which is a typical semi-curlydwarf.
330.	A good vigorous type.
348.	Units 1, 4, and 5, very vigorous; other two very good type.
310.	First unit with curlydwarf tendencies; others very vigorous.

Of these 22 lines, only 9 were noted as having uniformly good vine characteristics in 1918. Eight contained four or more hills with degenerate tendencies, and 5 showed variations in vigor which possibly might have been attributed to soil but which may, on the other hand, turn out to be the first signs of degeneration. Yield records do not promise to be very effective in dealing with degeneration. It is true that those lines which have appeared frequently among the lowest-yielding are typical degenerates, but degenerate tendencies are also noticeable among the high-yielding ones. On the other hand, 7 of the 19 lines noted with good vine characteristics in 1918 have each appeared once among the low-yielding 20 in Table IV. This indicates that low yields are not always associated with degeneration.

The number of tubers produced in the hill is often suggested as a point worth considering in making seed-potato selections. In Table V will be found a summary of numerical tuber production in the 108 Green Mountain tuber lines. There is a maximum variation in the 3-year averages of 3.45 tubers per single-stemmed hill. The 20 ranking highest in

numerical tuber production (Table VI) have as a group a 3-year average record of 4.04 tubers per hill, while the 20 ranking lowest (Table VII) have averaged for the 3-year period 2.40 tubers per hill. The number of tubers produced in the hills varies from year to year, as will be shown in the yearly averages of the different lines. The 108 Green Mountain lines averaged 1.96 tubers per hill in 1916, 3.97 in 1917, and 2.78 in 1918. Variable soil moisture conditions during the setting period are no doubt responsible for a goodly portion of this fluctuation in tuber production, although delayed thinning may have contributed to the low yields of 1916. In a general way, numerical tuber production and production by weight rise and fall together, but this is by no means a fixed rule. Lines of this variety show the greatest variance in numerical tuber production, but this is no doubt accounted for by the more pronounced degenerate tendencies among a larger proportion of these lines. Degenerate lines do not fall off so much in total number of tubers produced, but a larger proportion of the tubers grade below marketable size. Once degeneration begins in this variety, the line rapidly loses in vitality and yielding power. To illustrate this we might call attention to the record of line 345. This yielded 15,680 pounds per acre in 1916, while the average of all Green Mountain lines for that year was 11,335 pounds. In 1917 it yielded 14,402 pounds as compared with an average of 26,595 for all Green Mountain lines; and in 1918 it yielded 1,366 pounds, as compared with an average of 17,494 for all these lines. Expressed in plus and minus variations, this line yielded 4,345 pounds above the average in 1916, 12,193 below the average in 1917, and 16,127 below the average in 1918.

TABLE V.—*Three-year average numerical production of marketable tubers per hill from 108 Green Mountain tuber lines*

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
300	3.56	328	3.12	355	3.69	382	3.95
301	3.22	329	3.65	356	2.79	383	4.27
302	3.22	330	4.18	357	3.40	384	3.05
304	3.30	331	3.29	358	2.90	385	2.13
305	2.88	332	4.64	359	3.04	386	3.11
306	3.74	333	4.36	360	2.83	387	2.72
307	2.13	334	2.75	361	3.06	388	3.72
308	2.92	335	3.54	362	3.84	389	2.71
309	2.95	336	3.02	363	3.37	390	3.63
310	3.75	337	2.79	364	3.20	391	3.97
311	3.50	338	4.06	365	3.45	392	2.93
312	2.88	339	2.65	366	3.13	393	3.20
313	3.06	340	3.21	367	3.50	394	3.81
314	3.16	341	2.90	368	2.57	395	3.57
315	3.11	342	3.02	369	2.44	396	3.93
316	3.30	343	3.84	370	2.16	397	2.83
317	3.48	344	1.19	371	3.11	398	3.68
318	3.34	345	1.95	372	3.42	399	3.36
319	3.36	346	2.95	373	4.32	400	3.62
320	3.88	347	2.59	374	2.70	401	3.16
321	2.78	348	3.40	375	3.14	402	2.40
322	3.16	349	2.56	376	4.41	403	3.30
323	3.50	350	3.09	377	3.53	404	4.43
324	3.75	351	3.30	378	3.38	405	3.23
325	3.27	352	2.87	379	2.68	406	3.86
326	3.61	353	2.93	380	2.78	407	2.83
327	3.43	354	3.93	381	1.86	408	2.30

TABLE VI.—*Twenty highest-yielding of 108 Green Mountain tuber lines when ranked on 3-year average numerical production of marketable tubers per hill* [a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
*332	4.64	*383	4.27	396	3.93	*362	3.84
*404	4.43	*330	4.18	*354	3.93	394	3.81
*376	4.41	*338	4.06	*320	3.88	*324	3.75
*333	4.36	*391	3.97	406	3.86	310	3.75
*373	4.32	382	3.95	*343	3.84	*306	3.74

[a] The 15 starred lines also appear among the 20 highest-yielding when ranked on the 3-year average production of marketable tubers by weight. Ten of these lines, printed in bold-face type, appear among the 19 lines selected in 1918 as having uniformly good vine characteristics. Average of group, 4.40 tubers per hill.

TABLE VII.—*Twenty lowest-yielding of 108 Green Mountain tuber lines when ranked on 3-year average numerical production of marketable tubers per hill* [a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
*344	1.19	*370	2.16	*368	2.57	389	2.71
*381	1.86	*408	2.30	*347	2.59	387	2.72
*345	1.95	*402	2.40	*339	2.65	334	2.75
*385	2.13	369	2.44	379	2.68	321	2.78
307	2.13	*349	2.56	*374	2.70	380	2.78

[a] The 12 lines starred also appear among the 20 ranking lowest in weight of marketable tubers. None of these 20 low-yielding lines have good vine characteristics. Average of group, 2.40 tubers per hill.

The 19 lines selected in 1918 as having uniformly good vine characteristics have been grouped in Table VIII. The 1918 average of these 19 lines is 26,260 pounds. In Table IX appear an equal number of the heaviest-yielding lines of 1918, with an average production for the year of 29,267 pounds. The 108 Green Mountain lines gave an average yield of 17,493 pounds in 1918. It will be noted that selection based upon vine characteristics alone came very near isolating the high-yielding lines for that season. The 19 lines appearing in Table VIII have as a group a 3-year average record of 23,270 pounds of marketable tubers per acre. The 19 lines standing highest when ranked on their 3-year average yield of marketable tubers have as a group an average of 25,131 pounds. The variation between the two groups, 1,861 pounds per acre, hardly seems sufficient to repay the labor involved in keeping yield records.

TABLE VIII.—*Yields of 19 Green Mountain lines chosen upon vine characteristics alone as the best of the 108 lines of this variety in 1918* [a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
300	26,071	*338	22,738	*372	31,296	394	20,674
*317	23,472	340	24,262	377	22,997	396	25,088
*330	30,318	348	30,715	*383	22,983	400	29,269
*332	29,424	355	20,293	*390	28,362	*404	22,713
*333	25,320	*362	29,966	*391	32,989		

[a] The lines starred appear among the 20 highest-yielding lines when ranked on the 3-year average production by weight of marketable tubers. Average of group, 26,260 pounds per acre.

TABLE IX.—*Nineteen highest-yielding of 108 Green Mountain lines in 1918* [a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
391	**32,986**	320	30,663	306	29,340	361	26,714
372	**31,296**	**330**	**30,318**	**400**	**29,269**	310	26,482
354	31,128	376	30,073	398	28,572	343	26,249
363	30,807	**362**	**29,966**	**390**	**28,362**	**300**	**26,017**
348	**30,715**	**332**	**29,424**	388	27,873		

[a] The lines printed in bold-face type also appear in the group with good vine characteristics. This leaves 10 of the 19 lines with vines suggesting degenerate tendencies. Average of group, 29,267 pounds per acre.

RURAL NEW YORKER TUBER LINES 409 TO 516

Rural New Yorker has ranked very high in the variety tests conducted at this Station. Experience would lead to the belief that, with the possible exception of Russet Burbank, no main crop variety tested in these experiments will give more uniformly satisfactory results upon heavy types of irrigated land. Usually little difficulty is experienced in maintaining good, vigorous stock where the seed is carefully selected after the digger. The average yield of all strains of Rural tested in 1916, 1917, and 1918 was 13,449 pounds of marketable tubers per acre. It will be noted that the average yield of the 108 tuber lines for the same period was 16,820 pounds. The 3-year performance record of these lines is presented in Table X. Here, as well as in Table II, it is interesting to note the variation in the average annual yield of all lines for the three seasons. Within any one season the variation between tuber lines is not so pronounced as it is in Green Mountain; but as yet none of these lines has reached the final stage of degeneration as several Green Mountain lines have. No effort is made to draw conclusions from Table X as a whole, but in Tables XI and XII an effort has been made to present a portion of the data included in Table X in such form that we may get some idea of the value of a 3-year performance record in isolating high-yielding lines.

TABLE X.—*Three-year summary of yields of marketable tubers per acre from 108 Rural New Yorker tuber lines*

Tuber line No.	1916	1917	1918	3-year average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
409	12,776	22,007	17,422	17,401
410	9,872	20,907	18,351	16,376
411	9,292	22,300	22,956	18,182
412	13,357	26,327	24,939	21,541
413	9,292	27,876	15,648	17,605
414	9,872	23,230	26,585	19,895
415	12,776	25,919	23,961	20,885
416	12,776	21,371	28,108	20,751
417	8,130	24,623	22,683	18,478
418	4,065	17,869	14,867	12,267
419	11,034	24,159	20,442	18,545
420	7,549	24,159	20,442	17,383
421	8,711	25,088	18,584	17,461

TABLE X.—*Three-year summary of yields of marketable tubers per acre from 108 Rural New Yorker tuber lines*—Continued

Tuber line No.	1916	1917	1918	3-year average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
422	11,615	28,340	17,190	19,048
423	12,776	23,230	14,867	16,957
424	11,615	27,386	24,049	21,017
425	8,711	21,836	28,362	19,636
426	8,711	24,159	21,165	18,011
427	10,453	21,836	17,654	16,647
428	1,742	34,070	18,351	18,054
429	7,742	22,765	16,626	15,711
430	6,388	23,230	26,650	18,756
431	6,388	26,946	17,551	16,961
432	9,291	25,430	15,159	16,626
433	9,872	26,482	24,623	20,325
434	6,969	27,031	26,714	20,238
435	7,549	23,230	21,516	17,431
436	6,969	23,230	22,765	17,654
437	8,130	25,088	18,119	17,112
438	6,388	21,836	18,582	15,602
439	6,388	20,442	25,428	17,419
440	9,292	23,230	21,371	17,964
441	6,969	22,300	20,132	16,467
442	6,388	24,623	27,873	19,628
443	10,453	25,088	27,876	21,139
444	10,453	19,048	17,035	15,512
445	11,615	19,513	19,977	17,035
446	11,613	26,482	19,745	19,280
447	9,292	16,002	21,589	15,627
448	13,938	24,452	23,229	20,539
449	12,776	23,694	17,422	17,964
450	12,195	23,230	25,142	20,189
451	11,034	25,430	25,428	20,630
452	11,034	26,017	20,648	19,233
453	6,388	26,017	13,938	15,447
454	5,807	14,402	18,093	12,767
455	10,453	22,765	19,048	17,422
456	11,615	13,938	17,035	14,196
457	12,195	23,230	10,758	15,394
458	9,292	22,300	19,071	16,887
459	9,292	22,765	17,654	16,570
460	11,034	20,442	20,049	17,175
461	9,292	20,907	13,473	14,557
462	10,453	24,159	19,071	17,894
463	11,034	16,261	16,519	14,604
464	8,711	23,230	17,035	16,325
465	8,130	19,048	24,939	17,372
466	8,130	21,836	18,093	16,019
467	7,549	23,694	18,093	16,445
468	5,807	19,676	13,692	13,058
469	9,872	19,513	20,907	16,764
470	5,807	22,300	20,538	16,215
471	5,226	19,977	18,582	14,595
472	7,549	16,261	18,351	14,053
473	5,807	18,119	17,359	13,761
474	7,549	19,977	17,422	14,982
475	6,969	20,442	17,035	14,815
476	8,130	23,694	20,442	17,422
477	5,807	19,513	12,544	12,621
478	8,130	22,300	18,067	16,165
479	8,711	19,513	18,857	15,693
480	10,453	23,230	22,409	18,697

TABLE X.—*Three-year summary of yields of marketable tubers per acre from 108 Rural New Yorker tuber lines*—Continued

Tuber line No.	1916	1917	1918	3-year average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
481	10,453	16,725	17,035	14,737
482	11,615	18,584	20,538	16,912
483	9,292	16,261	11,247	12,266
484	8,711	12,195	17,551	12,819
485	11,615	20,907	18,119	16,880
486	10,453	17,654	24,049	17,385
487	9,292	18,119	21,371	16,260
488	5,807	19,048	19,048	14,634
489	6,969	18,584	22,494	16,015
490	10,453	18,584	13,692	14,243
491	11,613	22,300	17,887	17,266
492	8,711	23,694	23,488	18,631
493	11,615	18,584	18,826	16,341
494	9,872	20,442	16,260	15,524
495	12,195	19,048	19,315	16,852
496	13,938	19,513	21,760	18,403
497	10,453	23,694	20,674	18,273
498	8,130	19,513	22,455	16,699
499	8,130	21,029	17,190	15,449
500	4,646	22,300	14,670	13,872
501	4,646	22,765	22,765	16,725
502	6,969	22,765	19,977	16,570
503	6,388	20,907	19,513	15,602
504	4,646	23,230	20,442	16,106
505	9,872	18,584	18,093	15,516
506	4,646	24,623	20,049	16,439
507	5,226	19,048	21,516	15,263
508	7,549	21,371	17,115	15,345
509	8,711	21,029	12,389	14,043
510	4,646	25,088	25,552	18,428
511	8,711	21,836	19,560	16,702
512	6,969	22,300	19,560	16,276
513	6,969	22,300	20,674	16,647
514	6,969	22,300	20,442	16,570
515	9,292	22,300	17,654	16,415
516	8,130	17,190	20,907	15,409
Average	8,831	21,864	19,787	16,820

The data included in these tables indicate that with few exceptions high-yielding lines are not consistent high yielders, neither are all low-yielding lines consistent low yielders. The following brief field notes taken in 1918 do not indicate that yield records will be found very satisfactory in dealing with degeneration. For instance, line 448 has a very good performance record. It ranked first in 1916, appeared among the highest-yielding 20 in 1918, only missed by a narrow margin a place among the best 20 in 1917, and ranks seventh according to the 3-year average. But unless the vine characteristics are very deceiving, its yielding power will drop at least 50 per cent during the next two years. One-third of these lines with promising performance records contained some plants with degenerate tendencies. The field notes of 1918 indicate to what extent degeneration appears among the lines that have appeared for at least two out of three years among the 20 highest-yielding or would be ranked with the 20 highest according to the 3-year average.

TABLE XI.—*Twenty highest annual rankings and 3-year average rankings from 108 Rural New Yorker tuber lines*[a]

1918		1917		1916		3-year average.	
Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
*425	28, 362	*428	34, 070	448	13, 938	***412	21, 541
**416	28, 108	**422	28, 341	*496	13, 938	**443	21, 139
**443	27, 876	*413	27, 876	412	13, 357	***424	21, 017
**442	27, 873	424	27, 387	415	12, 777	***415	20, 885
**434	26, 714	434	27, 031	*449	12, 777	**416	20, 751
*430	26, 650	*431	26, 947	*423	12, 777	**451	20, 630
*414	26, 585	433	26, 482	416	12, 777	**448	20, 539
**510	25, 552	**446	26, 482	*409	12, 777	**433	20, 325
**451	25, 428	412	26, 327	*495	12, 196	**434	20, 238
*439	25, 438	*453	26, 081	*457	12, 196	**450	20, 189
**450	25, 142	*452	26, 081	450	12, 196	*414	19, 895
*465	24, 939	415	25, 920	424	11, 615	*425	19, 636
***412	24, 939	451	25, 430	422	11, 615	**442	19, 628
**433	24, 623	*432	25, 430	*493	11, 615	**446	19, 280
***424	24, 049	510	25, 088	*485	11, 615	*452	19, 233
*486	24, 049	443	25, 088	*482	11, 615	**422	19, 048
***415	23, 961	*437	25, 088	*456	11, 615	*430	18, 756
*492	23, 488	*421	25, 088	*455	11, 615	480	18, 697
**448	23, 229	442	24, 624	446	11, 614	*492	18, 631
*411	22, 956	*506	24, 624	*491	11, 614	419	18, 545
		*417	24, 624				

[a] The number of stars indicates how many times the line has appeared among the 20 highest rankings. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. Three lines appear three times, 11 lines appear twice, and 30 lines appear only once.

TABLE XII.—*Twenty lowest annual rankings and 3-year average rankings from 108 Rural New Yorker tuber lines*[a]

1918		1917		1916		3-year average.	
Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
*457	10, 758	*484	12, 196	*428	1, 742	**483	12, 266
**483	11, 247	456	13, 938	418	4, 065	***418	12, 267
*509	12, 389	*454	14, 403	*506	4, 646	**477	12, 621
**477	12, 544	*447	16, 003	*510	4, 646	*454	12, 767
*461	13, 473	*472	16, 261	*504	4, 646	*484	12, 819
**468	13, 692	463	16, 261	*501	4, 646	**468	13, 058
**490	13, 692	483	16, 261	500	4, 646	**473	13, 761
**453	13, 938	481	16, 726	507	5, 227	**500	13, 872
**500	14, 670	*516	17, 190	*471	5, 227	*509	14, 043
***418	14, 867	*486	17, 665	473	5, 808	*472	14, 053
*423	14, 867	418	17, 869	*450	5, 808	**456	14, 196
*432	15, 159	**473	18, 119	468	5, 808	**490	14, 243
*413	15, 648	*487	18, 119	477	5, 808	*461	14, 557
*494	16, 260	*489	18, 584	488	5, 808	*471	14, 595
**463	16, 519	490	18, 584	*470	5, 808	**463	14, 604
*429	16, 626	*505	18, 584	*442	6, 388	**488	14, 634
**481	17, 035	*482	18, 584	453	6, 388	**481	14, 737
*464	17, 035	*493	18, 584	*431	6, 388	*475	14, 815
*475	17, 035	*495	19, 049	*503	6, 388	474	14, 982
**456	17, 035	**488	19, 049	*439	6, 388	**507	15, 262
**444	17, 035	444	19, 049	*430	6, 388		
		*465	19, 049	*438	6, 388		
		**507	19, 049				

[a] The number of stars indicates how many times the line has appeared among the 20 lowest rankings. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. One appears three times, 13 lines appear twice, and 37 lines appear only once.

Of these 21 lines, 7 have curlydwarf tendencies. Twelve appear among the best 33 lines chosen in 1918 on vine characteristics alone. This leaves two, 443 and 452, in the doubtful list.

LINE NO.	REMARKS.
416.	Third unit a curlydwarf; others vigorous though lacking in uniformity.
443.	A very good type; first and second unit not especially vigorous.
442.	A good vigorous type.
434.	A good vigorous type.
510.	A good vigorous type.
451.	A good vigorous type.
450.	Not a very good type.
412.	Uniform and fairly vigorous.
433.	A good vigorous type.
424.	Vines not a good type.
415.	A good type and fairly vigorous.
448.	All have more or less curlydwarf tendency.
422.	Lacking in vigor but type good.
446.	First four units have curlydwarf tendencies.
414.	First unit with curlydwarf tendencies.
425.	Very good and vigorous type.
452.	Not very vigorous but type good.
430.	First unit very vigorous; others good.
480.	Fairly vigorous.
492.	A very good type.
419.	Some curlydwarf tendencies.

In Table XIII data are presented showing the 3-year average numerical production of tubers per single-stemmed hill. In Tables XIV and XV a portion of this data is used to show the lack of correlation between yields in numbers and in weight, as well as the relation between numerical tuber production and good vine characteristics. There is in Table XIII a maximum variation of 1.29 tubers per hill. Between the average of the 20 highest and 20 lowest (Tables XIV and XV) there is a variation of 0.79 tubers per hill. Considering that these are single-stemmed hills, this variation is rather pronounced. But the data are apparently no more reliable than weight records in pointing out promising lines. Low numerical tuber production does not always mean low production by weight, and such records are apparently of little value as a check on degenerate tendencies. Fluctuation in tuber production in different seasons has been even greater than the variation between lines in any one season. These 108 lines averaged 2.05 marketable tubers per hill in 1916, 3.78 in 1917, and 2.44 in 1918.

In Table XVI the 33 lines with promising vine characteristics have been assembled with their 1918 yields of marketable tubers. The average yield of these 33 lines is 21,142 pounds per acre. In Table XVII the 33 heaviest-yielding lines of 1918 are assembled for comparison. Their average yield is 24,109 pounds, while the 1918 average of the 108 Rural New Yorker lines was 19,787 pounds per acre. The lines chosen upon vine

characteristics alone yielded well above the average of the 108 lines but did not equal the 33 heaviest-yielding lines of 1918. Field notes show that 15 of these heavy-yielding lines of 1918 have poor vine characteristics. This means that if mass selection based on tuber characteristics is practiced within these 15 lines their progeny will be almost certain to contain some rather advanced degenerate types that will materially decrease the yield of the lines in 1919. On the other hand, we can be almost sure that no well-advanced or low-yielding degenerates will appear among the 1919 progeny of those with good 1918 vine characteristics. It is interesting to go back beyond the 1918 records and compare the 3-year performance of these lines assembled in Table XVI with the 33 highest-yielding Rural New Yorker lines when ranked upon their 3-year average production. The 33 lines in Table XVI have produced during the 3-year period an average yield of 17,740 pounds per acre. The 33 of the 108 Rural New Yorker lines ranking highest according to the 3-year average production by weight have yielded on an average 19,181 pounds. Between the two groups there is a variation of 1,441 pounds in favor of the 33 lines ranked upon their performance record. But when vine development so nearly foretells the yielding power of the line it would really seem that this is a more practical basis for selection than yields measured in either weight or number of tubers.

TABLE XIII.—*Three-year average numerical production of marketable tubers per hill from 108 rural New Yorker tuber lines*

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
409	3.30	436	3.29	463	3.00	490	2.76
410	3.47	437	3.02	464	3.07	491	2.79
411	3.65	438	3.18	465	3.02	492	3.16
412	3.34	439	3.00	466	2.90	493	2.83
413	3.25	440	2.95	467	3.04	494	2.69
414	2.80	441	3.19	468	2.60	495	2.93
415	3.19	442	3.48	469	3.10	496	2.83
416	3.31	443	2.68	470	3.04	497	3.25
417	2.97	444	3.04	471	2.65	498	2.78
418	2.86	445	3.09	472	3.06	499	2.79
419	3.63	446	3.32	473	3.11	500	2.83
420	3.54	447	3.10	474	3.06	501	3.29
421	3.34	448	3.07	475	3.02	502	3.06
422	3.56	449	2.88	476	2.77	503	2.72
423	2.97	450	3.04	477	2.95	504	2.93
424	3.15	451	3.21	478	3.16	505	2.64
425	3.53	452	3.38	479	3.21	506	3.60
426	3.59	453	3.20	480	3.04	507	3.27
427	3.00	454	2.93	481	3.02	508	2.74
428	2.55	455	2.81	482	2.95	509	2.60
429	3.20	456	2.78	483	2.55	510	3.19
430	3.41	457	2.86	484	2.92	511	3.11
431	3.28	458	3.04	485	2.95	512	3.09
432	3.48	459	3.29	486	3.19	513	3.43
433	3.43	460	3.16	487	2.88	514	2.75
434	3.74	461	2.70	488	2.93	515	2.79
435	3.25	462	2.90	489	3.02	516	2.45

TABLE XIV.—*Twenty highest-yielding of 108 Rural New Yorker tuber lines when ranked on 3-year average numerical production of marketable tubers per hill*[a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
***434**	**3.74**	***422**	**3.56**	410	3.47	***412**	**3.34**
411	3.65	420	3.54	***433**	**3.43**	421	3.34
*419	3.63	***425**	**3.53**	**513**	**3.43**	*446	3.32
506	**3.60**	432	3.48	***430**	**3.41**	*416	3.31
426	3.59	***442**	**3.48**	*452	3.38	409	3.30

[a] The 11 lines starred appear among the 20 highest when ranked on 3-year average production by weight of marketable tubers. Nine of these lines (printed in bold-face type) have uniformly good vine characteristics, and the other 11 have vine characteristics which suggest degeneration. Average of group, 3.47 tubers per hill.

TABLE XV.—*Twenty lowest-yielding of 108 Rural New Yorker tuber lines when ranked on 3-year average numerical production of marketable tubers per hill*[a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
516	**2.45**	505	2.64	**503**	**2.72.**	*456	2.78
*483	2.55	*471	2.65	**508**	**2.74**	**498**	**2.78**
428	**2.55**	443	2.68	**514**	**2.75**	491	2.79
*509	2.60	494	2.69	*490	2.76	499	2.79
*468	2.60	*461	2.70	476	2.77	515	2.79

[a] The 7 lines starred appear among the 20 lowest when ranked on 3-year average production by weight of marketable tubers. The 6 lines printed in bold-face type appeared among the 33 chosen in 1918 as having the best vine characteristics, and these 6 have very good 3-year averages for tuber production by weight. Line 428 appeared among the heaviest-yielding 20 in 1918 and only missed by a small margin a place among the 20 heaviest-yielding when ranked on 3-year average production. Average of group, 2.68 tubers per hill.

TABLE XVI.—*Yields for 1918 of 33 Rural New Yorker lines chosen upon 1918 vine characteristics alone as the best of the 108 lines of this variety*[a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
*412	24,939	*442	27,873	*492	23,488	504	20,442
*413	15,648	*451	25,428	493	18,826	506	20,049
*415	23,961	465	24,939	495	19,315	507	21,516
*422	17,190	*480	22,409	*496	21,760	508	17,115
*425	28,362	486	24,049	*497	20,674	*510	25,552
*428	18,351	488	19,048	498	22,455	513	20,674
*430	26,650	489	22,494	501	22,765	514	20,442
*433	24,623	491	17,887	503	19,513	516	20,907
*434	26,714						

[a] The 16 lines starred appear among the 33 highest-yielding lines when ranked on their 3-year average record. Lines 488 and 507 rank among the 20 lowest-yielding according to the 3-year average. Average of group, 21,142 pounds per acre.

TABLE XVII.—*Thirty-three highest-yielding lines of 108 Rural New Yorker tuber lines in 1918*[a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
425	**28,362**	**451**	**25,428**	**492**	**23,488**	**480**	**22,409**
416	28,108	450	25,142	448	23,229	**496**	**21,760**
443	27,876	**412**	**24,939**	411	22,956	447	21,589
442	**27,873**	**465**	**24,939**	436	22,765	435	21,516
434	**26,714**	**433**	**24,623**	**501**	**22,765**	**507**	**21,516**
430	**26,650**	424	24,049	417	22,683	440	21,371
414	26,585	**486**	**24,049**	**489**	**22,494**	487	21,371
510	**25,552**	**415**	**23,961**	**498**	**22,455**	426	21,156
439	25,428						

[a] The 18 lines printed in bold-face type appear in Table XVI. This means that of the 33 highest-yielding Rural New Yorker lines in 1918, 15 have poor vine characteristics. Average of group, 24,109 pounds per acre.

EARLY SIX WEEKS TUBER LINES 517 TO 622

While these lines were selected from stock being grown under the name of Early Six Weeks, they all seem more typical of Red Early Ohio. At first a mixture of Early Ohio and Early Six Weeks was suspected, but observations on vine characteristics have led to the belief that the less vigorous lines, more typical of Early Six Weeks, are nothing more than degenerate types of Early Ohio. Such types are constantly appearing within vigorous dark green lines typical of Early Ohio. With this explanation I will still refer to these as Early Six Weeks lines. Varieties of the Early Ohio types have proved very satisfactory under soil and climatic conditions at the Station, yielding much better than other standard early varieties like Irish Cobbler and Early Triumph, and with less tendency to degeneration.

The 3-year performance record of these 100 lines is presented in Table XVIII. The average annual yield has followed about the same curve as in the other two varieties. There has apparently been ample variation between lines in any one season and in the 3-year average to furnish a basis for selection. As in the other varieties, however, these variations in yield have in many cases been rather inconsistent.

TABLE XVIII.—*Three-year summary of yields of marketable tubers per acre from 100 Early Six Weeks tuber lines*

Tuber line No.	1916	1917	1918	3-year average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
517	15,099	20,907	19,513	18,506
518	16,261	21,681	8,802	15,581
519	10,453	24,159	17,654	17,422
520	9,872	24,004	11,247	15,041
522	12,195	28,340	19,804	20,113
523	12,195	20,907	13,692	15,598
524	13,357	21,371	13,008	15,912
525	14,518	16,958	21,271	17,582
526	12,776	23,230	20,293	18,766
527	13,357	19,977	11,150	14,828
528	11,615	22,300	12,469	15,461
529	13,938	26,482	18,351	19,590
530	15,099	22,765	15,099	17,654
531	12,776	27,565	22,713	21,018
532	16,261	22,997	18,584	19,280
533	16,261	25,320	21,271	20,950
534	11,615	14,402	15,099	13,705
535	6,969	22,765	16,725	15,486
536	8,711	25,088	18,119	17,306
537	11,615	22,300	15,331	16,415
538	9,292	19,977	11,615	13,628
539	7,549	21,836	19,048	16,144
540	8,711	24,159	19,977	17,615
541	11,615	22,765	21,603	18,661
542	9,292	20,648	18,119	16,019
543	12,776	18,351	22,300	17,809
545	6,969	17,654	7,652	10,758
546	9,872	25,088	22,765	19,308
547	9,292	24,624	13,473	15,796
548	11,034	26,017	25,320	20,790

TABLE XVIII.—*Three-year summary of yields of marketable tubers per acre from 100 Early Six Weeks tuber lines*—Continued

Tuber line No.	1916	1917	1918	3-year average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
549	13,938	25,553	24,391	21,294
550	12,195	21,528	19,745	17,822
551	19,745	24,623	25,553	23,307
552	17,422	25,088	25,553	22,687
553	10,453	14,228	14,181	12,954
554	9,872	25,553	20,907	18,777
555	9,292	19,745	13,936	14,324
556	13,357	20,540	15,099	16,332
558	12,195	26,186	20,049	19,476
559	8,711	17,654	17,887	14,750
560	12,776	17,422	20,538	16,912
561	9,292	20,442	29,502	19,745
562	12,776	19,978	27,873	20,209
563	15,099	13,473	12,958	13,843
564	11,034	23,694	19,048	17,925
565	15,680	23,229	20,907	19,938
566	11,034	19,745	13,203	14,660
568	11,615	37,942	14,634	21,397
569	15,680	16,725	20,210	17,538
570	12,195	18,584	15,648	15,475
571	10,453	18,816	21,139	16,802
572	12,776	22,300	18,351	17,809
573	9,292	15,331	15,564	13,395
574	8,130	21,836	16,028	15,331
575	10,453	21,139	19,977	17,189
576	10,453	17,190	14,402	14,015
577	17,422	26,017	19,513	20,984
578	15,099	20,907	13,241	16,415
579	14,518	21,371	14,181	16,690
580	15,099	23,694	21,271	20,021
581	13,938	22,300	16,397	17,545
582	12,776	24,452	13,241	16,823
583	14,518	25,553	10,918	16,996
584	14,518	33,683	19,071	22,424
585	9,292	32,986	19,048	20,442
586	12,195	26,017	20,210	19,474
588	12,195	28,908	14,425	18,509
589	15,099	31,360	20,132	22,197
590	10,453	23,230	16,028	16,570
591	12,776	24,159	20,907	19,280
592	13,938	24,623	9,524	16,028
593	14,518	28,968	13,938	19,141
594	15,099	26,548	17,654	19,767
595	12,195	30,663	21,027	21,295
596	14,518	30,199	17,359	20,692
597	11,615	28,340	13,473	17,809
599	11,615	25,088	10,685	15,796
600	10,453	26,017	17,654	18,041
601	7,549	27,876	19,048	18,157
602	11,615	25,533	10,513	15,887
603	15,099	28,853	16,870	20,274
604	12,195	30,810	21,516	21,507
605	14,518	29,343	20,442	21,434
606	13,357	28,340	15,403	19,033
607	13,938	29,966	18,584	20,829
608	11,615	30,199	22,005	21,273
609	9,292	29,734	21,516	20,180
610	11,615	27,876	16,261	18,584
611	13,938	24,623	11,615	16,725

TABLE XVIII.—*Three-year summary of yields of marketable tubers per acre from 100 Early Six Weeks tuber lines*—Continued

Tuber line No.	1916	1917	1918	3-year average.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
612	15,099	29,734	15,331	20,054
613	12,195	25,088	16,137	17,806
614	15,099	29,269	18,584	20,984
615	11,034	25,088	13,473	16,531
616	13,938	25,919	12,544	17,467
617	13,938	27,876	18,582	20,132
618	15,099	30,663	19,048	21,603
619	9,292	25,088	15,564	16,648
620	11,034	21,518	18,119	16,890
621	8,711	16,725	4,646	10,027
622	12,195	26,485	19,358	19,345
Average	12,334	24,048	17,344	17,909

TABLE XIX.—*Twenty highest annual rankings and 3-year average rankings from 100 Early Six Weeks tuber lines* [a]

1918		1917		1916		3-year average.	
Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
*561	29,502	*568	37,942	551	19,746	**551	23,307
*562	27,873	**584	33,684	552	17,423	**552	22,687
**552	25,553	*585	32,987	*577	17,423	**584	22,424
**551	25,553	**589	31,361	*518	16,261	**589	22,197
*548	25,320	604	30,810	*532	16,261	**618	21,603
*549	24,391	*595	30,663	533	16,261	**604	21,507
*546	22,765	**618	30,663	565	15,680	**605	21,434
*531	22,713	608	30,119	*569	15,680	*568	21,397
*543	22,300	**596	30,119	*578	15,099	*595	21,295
**608	22,005	*607	29,966	580	15,099	*549	21,294
*541	21,603	609	29,734	*594	15,099	**608	21,273
**609	21,516	**612	29,734	589	15,099	*531	21,018
**604	21,516	**605	29,343	618	15,099	**614	20,984
**580	21,271	**614	29,269	612	15,099	*577	20,984
**525	21,271	**593	28,969	614	15,099	**533	20,950
**533	21,271	*588	28,908	603	15,099	*607	20,829
*571	21,139	**603	28,854	*563	15,099	*548	20,790
*595	21,027	*606	28,341	*530	15,099	**696	20,692
*591	20,907	*597	28,340	*517	15,099	*585	20,442
**565	20,907	*522	28,340	*583	14,518	**603	20,274
*554	20,907			525	14,518		
				*579	14,518		
				584	14,518		
				593	14,518		
				596	14,518		
				605	14,518		

[a] The number of stars indicates how many times the line has appeared among the 20 highest rankings. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. None appear three times, 18 appear twice, and 31 appear only once.

In Tables XIX and XX a portion of the data from Table XVIII is assembled for the purpose of a more critical study of the performance of the highest-yielding and lowest-yielding 20 of the 100 lines.

TABLE XX.—*Twenty lowest annual rankings and 3-year average rankings from 108 Early Six Weeks tuber lines*[a]

1918		1917		1916		3-year average.	
Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
***621	4,646	563	13,473	*535	6,969	***621	10,027
***545	7,652	*553	14,228	545	6,969	***545	10,758
*518	8,802	*534	14,402	*601	7,550	*553	12,954
*592	9,524	**573	15,332	*539	7,550	**573	13,395
*602	10,513	*569	16,725	*574	8,131	***538	13,628
*599	10,685	621	16,726	*536	8,711	*534	13,705
*583	10,918	*525	16,958	*540	8,711	**563	13,843
*527	11,150	*576	17,190	621	8,711	*576	14,015
**520	11,247	*560	17,422	559	8,711	**555	14,324
*611	11,615	**559	17,654	538	9,292	**566	14,660
***538	11,615	545	17,654	555	9,292	**559	14,750
*528	12,469	*543	18,351	573	9,292	*527	14,828
*616	12,544	*570	18,584	561	9,292	**520	15,041
**563	12,958	*571	18,816	*542	9,292	*574	15,331
*524	13,008	**555	19,745	*609	9,292	*528	15,461
**566	13,203	566	19,746	*585	9,292	*570	15,475
*578	13,241	*527	19,977	*619	9,292	*535	15,486
*582	13,241	538	19,977	547	9,292	*518	15,581
**547	13,473	*562	19,978	*546	9,872	523	15,598
*597	13,473	**561	20,442	*554	9,872	**547	15,796
*615	13,473			*505	9,872	*599	15,796
				520	9,872		

[a] The number of stars indicates how many times the line has ranked among the lowest 20. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. Three appear three times, 8 appear twice, and 38 appear only once.

It will be noted from Tables XIX and XX that in either case the greater number of these lines have appeared only once in either of these groups. Line 561 appears in the low-yielding groups of 1916 and 1917 but is the highest-yielding line of 1918. It also appears among the 40 lines selected in 1918 as having the best vines. While the performance record may not so indicate, it is undoubtedly one of the good lines of this variety. Aside from this one line, none of those that have ranked twice among the lowest 20 according to the 3-year average appear among those selected in 1918 as having good vine characteristics. We may safely say that the performance record is more reliable as a means of eliminating the lowest-yielding lines than in pointing out the higher-yielding ones. The following 1918 field notes show that in this as well as in the other varieties yield records will not eliminate lines with degenerate tendencies.

LINE NO.	REMARKS.
552.	A good dark green type.
551.	A good dark green type.
608.	A good dark green type.
609.	A good dark green type.
604.	A good dark green type.
580.	A good dark green type.
525.	Third unit lacking in color; others good.
584.	A good dark green type.
589.	First unit not a good type.
618.	A good dark green type.
596.	A good dark green type.
612.	First unit lacking in color.
605.	A good dark green type.
614.	Third, fourth, and fifth units not good type.
593.	Color not good although the line is quite vigorous.
603.	A good dark green type.
568.	Lacking in color but fairly vigorous.
595.	A good dark green type.
549.	A good dark green type.
531.	Last unit showing a tendency to burn.
577.	A good dark green type.
607.	A good dark green type.
548.	A good dark green type.
585.	Last unit light-colored and burning; others very good.

Of these 26 lines which have appeared at least twice among the highest-ranking 20 or would be ranked among the highest 20 on their 3-year average production by weight, 17 have good records as to vine characteristics and 9 contain some vines of a degenerate type. It will be remembered that loss of vitality is indicated in this variety by a loss of color and a tendency for the leaves to burn about the edges in typical degenerates.

In Table XXI will be found data upon the 3-year average numerical tuber production of Early Six Weeks. The maximum variation found is 1.78 tubers per hill. The annual average tuber production shows even greater variation. These 100 tuber lines averaged 2.12 tubers per hill in 1916, 4.04 in 1917, and 2.63 in 1918. The 20 highest and 20 lowest yielding lines when ranked upon tuber production in numbers have been grouped in Tables XXII and XXIII. The first 8 lines starred in Table XXIII are typical degenerates with bad yield records by weight. There are, however, 5 lines in Table XXIII which also appear in Table XXIV among the 40 with good vine characteristics in 1918. Going back to Table XVIII, it will be noticed that these 5 lines have very good records when judged on tuber production by weight. It is true that none of them are high yielders, but they fall very close to the average of the 100 lines. Fourteen of the lines in Table XXII appear in Table XXIV, or among those selected in 1918 as having good vine characteristics.

TABLE XXI.—*Three-year average numerical production of marketable tubers per hill from 100 Early Six Weeks tuber lines*

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
517	3.02	543	2.77	571	3.18	597	3.25
518	2.41	545	2.41	572	3.20	599	3.22
519	2.84	546	3.29	573	2.70	600	3.15
520	2.69	547	3.25	574	3.15	601	3.29
522	3.00	548	3.65	575	3.27	602	3.27
523	3.07	549	3.63	576	2.84	603	3.47
524	2.86	550	2.92	577	3.95	604	3.85
525	3.23	551	3.50	578	3.00	605	3.25
526	2.90	552	3.11	579	2.86	606	3.32
527	2.79	553	3.17	580	3.23	607	3.50
528	3.16	554	3.11	581	3.40	608	3.95
529	3.45	555	3.18	582	3.48	609	3.90
530	3.13	556	3.23	583	3.20	610	3.11
531	3.27	558	3.33	584	3.64	611	2.97
532	3.47	559	2.93	585	3.50	612	3.43
533	3.69	560	2.86	586	3.30	613	3.23
534	2.72	561	3.36	588	3.00	614	3.40
535	3.00	562	3.39	589	3.78	615	2.77
536	2.79	563	2.65	590	3.34	616	3.11
537	3.43	564	3.40	591	3.40	617	3.16
538	2.81	565	3.00	592	3.29	618	3.52
539	3.15	566	2.74	593	3.39	619	3.00
540	3.12	568	3.80	594	2.93	620	3.02
541	3.47	569	3.06	595	3.81	621	2.17
542	3.02	570	2.79	596	3.60	622	3.28

TABLE XXII.—*Twenty highest of 100 Early Six Weeks tuber lines when ranked on 3-year average numerical production of marketable tubers per hill* [a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
*608	3.95	*568	3.80	*549	3.63	*607	3.50
*577	3.95	*589	3.78	*596	3.60	582	3.48
609	3.90	*533	3.69	*618	3.52	532	3.47
*604	3.85	*548	3.65	*551	3.50	541	3.47
*595	3.81	*584	3.63	*585	3.50	*603	3.47

[a] The lines starred also appear among the 20 highest-yielding when ranked on 3-year average production by weight. Thirteen of these lines (in bold-face type) have uniformly good vine characteristics; the other 7 lines contained plants suggesting degeneration. Average of group, 3.65 tubers per hill.

TABLE XXIII.—*Twenty lowest of 100 Early Six Weeks tuber lines when ranked on 3-year average numerical production of marketable tubers per hill* [a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
*621	2.17	*573	2.70	*527	2.79	*576	2.84
*518	2.41	*534	2.72	**536**	**2.79**	524	2.86
*545	2.41	*566	2.74	*570	2.79	**560**	**2.86**
*563	2.65	**543**	**2.77**	*538	2.81	578	2.86
*520	2.69	615	2.77	**519**	**2.84**	**526**	**2.90**

[a] The lines starred also appear among the 20 lowest yielding when ranked on 3-year average production by weight. The lines printed in bold-faced type appear among the 40 chosen in 1918 as having good vine characteristics. Average of group, 2.71 tubers per hill.

TABLE XXIV.—*Yields in 1918 of 40 Early Six Weeks tuber lines chosen upon 1918 vine characteristics alone as the best of the 100 lines of this variety* [a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
517	19,513	*549	24,391	569	20,210	601	19,048
519	17,654	*551	25,553	571	21,139	*604	21,516
*522	19,804	*552	25,553	575	19,977	*605	20,442
*526	20,293	*554	20,907	*577	19,513	*607	18,584
*529	18,351	*558	20,049	*580	21,271	*608	22,005
*532	18,584	560	20,538	*584	19,071	*609	21,516
536	18,119	*561	29,502	*591	20,907	610	16,261
540	19,977	*562	27,873	*594	17,654	*618	19,048
543	22,300	564	19,048	*595	21,027	620	18,119
*548	25,320	565	20,907	600	17,654	*622	19,358

[a] The 26 lines starred also appear among the 40 highest-yielding when ranked on the 3-year average tuber production by weight. The others have very good records for the 3-year period. Average of group, 20,713 pounds per acre.

The vine growth of the other 6 lines is reported in the following 1918 field notes:

LINE NO.	REMARKS.
568.	A little lacking in color but fairly vigorous.
589.	A very good type with possible exception of first unit.
533.	First unit light colored and burning; other plants green and vigorous.
596.	A very good green type; first two hills lacking in vigor, but this is possibly due to soil.
585.	Type fair with exception of last unit, which shows some burning.
582.	A light-colored, burning type.
541.	A good green type with exception of first unit, which is distinctly lighter and burning.

In Table XXIV data are assembled to show the relation between good vine characteristics and tuber production in Early Six Weeks. The 40 lines with best vine characteristics gave an average yield of 20,713 pounds per acre in 1918, while the 41 heaviest-yielding lines of 1918 grouped in Table XXV averaged 21,350 pounds. The 1918 average of the 100 Early Six Weeks lines was 17,344 pounds of marketable tubers per acre. In this variety vine growth is almost as reliable as yield records in pointing out high-yielding lines. The 3-year average yield of the 40 lines in Table XXIV was 19,515 pounds per acre, while the 40 lines ranking highest on 3-year average tuber production by weight yielded during the same period an average of 20,455 pounds. Will it pay to keep yield records when 40 per cent of the heaviest-yielding lines chosen with the aid of 3 years' data do not produce 1,000 pounds per acre more than do 40 per cent selected in less than 2 hours upon vine characteristics alone?

TABLE XXV.—*Forty-one highest-yielding of 100 Early Six Weeks lines in 1918* [a]

Line No.	Yield.	Line No.	Yield.	Line No.	Yield.	Line No.	Yield.
	Pounds.		*Pounds.*		*Pounds.*		*Pounds.*
561	29,502	604	21,516	560	20,538	550	19,745
562	27,873	609	21,516	605	20,442	517	19,513
551	25,553	525	21,271	526	20,293	577	19,513
552	25,553	533	21,271	569	20,210	622	19,358
548	25,320	580	21,271	586	20,210	584	19,071
549	24,391	571	21,139	589	20,132	539	19,048
546	22,765	595	21,027	558	20,049	564	19,048
531	22,713	554	20,907	540	19,977	585	19,048
543	22,300	565	20,907	575	19,977	601	19,048
608	22,005	591	20,907	522	19,804	618	19,048
541	21,603						

[a] The 31 lines printed in bold-face type also appear in Table XXIV. This leaves 10 of these high-yielding lines with poor vine characteristics. Average of group, 21,350 pounds per acre.

CONCLUSIONS

The data presented, so far as the author is able to judge, do not furnish very strong evidence of the presence of high-yielding lines within the common population of the varieties studied. The real test of the existence of such lines is ability to maintain a high-yielding progeny by indiscriminate mass selection.

Short performance records are fairly reliable in eliminating lines with low-yielding tendencies, but they are not so reliable as a basis upon which to select plus variations if such really exist.

If degenerate tendencies exist within certain clonal lines and not in others, short performance records are of little value in eliminating the undesirable lines.

Degenerate individuals appear with such persistent regularity within line selections as to become a real stumblingblock. If there are no exceptions to this rule, before a hill or tuber line can be increased to a point where it is of real value in commercial potato production it is almost certain to contain degenerate types which soon reduce its yielding power to that of the common population of the variety.

The data presented will not justify an indorsement of the plan of clonal line selection as a practical method of potato-seed improvement. This does not mean that the hill-selection method of choosing potato seed is without merit. Generally speaking, high-yielding hills selected upon production by weight will produce the following season a high-yielding progeny. It does mean, however, that to be effective hill selection becomes an annual task. I believe there is a more practical method of potato-seed improvement.

Since certain vine characteristics are so closely correlated with yields, selection based on vine development alone promises to be more reliable than selection based on tuber production either by weight or number, and much more practical.

At present, selection based chiefly on vine characteristics seems to be the only hope in dealing with degeneration. The success of such selection is measured by one's ability to identify intermediate types as well as typical curlydwarf degenerates.

A special seed plot in which the seed pieces from each tuber are planted in consecutive hills promises to afford the best solution of the problems of degeneration and the maintenance of high-yielding variety populations.

Seed for such a plot may be selected in one of two ways. Especially vigorous hills may be marked in the field during the growing season, and the crop from these may be dug and used for planting the special seed plot of the following season, or seed may be selected in the field at digging time or from the bin. The first method will insure the greater return from the first seed plot, especially if the field from which the seed is selected contains a large percentage of degenerate plants. In selecting seed in the field after the digger or from the bin, one may to a certain extent avoid degenerate types by observing certain tuber characteristics. (1) Choose seed tubers rather above the average size for the variety. (2) Select those that are long rather than short for the variety and with both ends full and rounded, not pointed. (3) Choose those that are oval rather than round in cross section, or, in other words, flattened tubers. (4) Pick tubers with conspicuous and moderately deep eyes.

The seed plot can best be planted by hand. The rows should be spaced the usual distance apart and the hills placed 12 or 15 inches apart in the row. On good, fertile, irrigated land, where the recommendations in regard to thinning are to be carried out, the hills should be spaced at 12 or even 10 inches apart. The tubers should be taken to the field whole and then cut as planted. The seed pieces may be cut rather small if seed is not abundant. Single-eye seed pieces weighing from ½ to 1 ounce will give just as good results as larger pieces. These are conveniently planted with a hoe, and if small should not be covered over 3 inches deep. Each tuber is cut by itself, and the pieces are dropped in consecutive hills. Not only is it important to have the hills from each tuber in a group, but it is desirable to have these groups marked off one from the other. This may be accomplished in several ways. A good way is to drop a hill of corn between the groups. The important point, however, is to have the hills from each tuber in a group. This is the only way if intermediate types are to be eliminated from the seed plot by roguing. Mixtures are also easily detected where the hills are in tuber groups.

The seed plot should be thinned by removing all but one stalk from each hill. Thinning should be done as soon as the vines are large enough to pull, usually from five to six weeks after planting. Proper comparisons can best be made between hills with a uniform number of stems, and this is the real object of thinning. But single-stemmed hills also produce tubers of a more uniform size, and this is desirable, especially if the seed stock is to be offered for sale. Regardless of the merits of the case, the public commonly thinks of good potato seed as uniform-sized stock.

Roguing the seed plot is the most important step in the production of good seed. This consists in going over the field several times during the season and removing undesirable hills. In the first place, there may be variety mixtures in the seed plot. These mixtures are detected chiefly by variations in foliage, color of blossoms, amount of blossoms produced, and dates of ripening. There will also be some weak and degenerate types and diseased hills to be removed. The plot should first be gone over about blooming time, as variety mixtures are then very likely to be most conspicuous. A group of hills may show blossoms that are off type in color, or a certain group of hills may bloom more or less than the other plants in the plot. These hills should be dug and the tubers removed from the field. A little later the plot should be gone over again to catch hills lacking in vigor or infected with disease. In early varieties, this examination should be made just about the time the most vigorous vines show signs of maturing. At this time some vines will be found fully mature. This premature ripening is probably brought on by disease, and the hills should be removed. Such hills most frequently appear at random, but occasionally all the hills from a seed tuber may be diseased. In looking for weak plants, the hills from each tuber should be studied as a group. Weak hills will show a more crinkled foliage and usually less vigorous vines. It is well to remember that the intermediate types are the real trouble makers. They are usually as vigorous as normal hills, but show a slight crinkling of the foliage and are very often of a lighter shade of green.[1] In looking for these weak groups it is best not to work too near the row being examined. First look each row over at close quarters and then from two or three rows distant. In roguing out late varieties, the work must always be done before the vines are touched with frost. Remember that in roguing the tubers as well as the vines must be dug and removed from the seed plot.

If the seed plot has been carefully rogued, the entire crop may be saved for seed. Occasionally a group of hills may produce tubers of poor form, and these may be discarded. The small seed from such a seed plot is just as satisfactory as the large, and in the great majority of cases variations in form are nothing more than fluctuations and as such are not transmitted to the following crop.

In many instances the improvement secured by growing a variety in a special seed plot of this kind for one season may be apparent for two or three years after returning to the practice of selecting seed at random from the field at digging time or from the bin; but permanent improvement can be maintained only by continuing the special seed plot year after year. With most varieties it is allowable, if the roguing is carefully done, to increase the seed secured from the seed plot by planting it in a certain part of the commercial field and then saving

[1] WHIPPLE, O. B. DEGENERATION IN POTATOES. Mont. Agr. Exp. Sta. Bul. 130, 29 p., 16 fig. 1919.

from this part of the field seed for the entire acreage the following season. But if one is not absolutely sure he can pick out the intermediate types in roguing, this practice may prove disappointing. Once the special seed plot is established, it may well be continued from year to year, the seed for the special seed plot of each year being selected from the seed plot of the year before. It is even advisable to go into the special seed plot and mark especially promising groups of hills to be dug to furnish seed for the seed plot of the following year.

OCCURRENCE OF THE FIXED INTERMEDIATE, HORDEUM INTERMEDIUM HAXTONI, IN CROSSES BETWEEN H. VULGARE PALLIDUM AND H. DISTICHON PALMELLA[1]

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INTRODUCTION

The cultivated barleys belong to the genus Hordeum and are characterized by the presence of three single-flowered spikelets at each node of the rachis. The floret of the central spikelet develops a normal kernel in all forms of barley. The lateral florets, on the other hand, may develop normal or undersized kernels or may be sterile or even abortive. In classifying the varieties, Harlan (*2*)[2] recognized four species, basing them on the degree of fertility in the lateral florets. Varieties of three of these species are concerned in the data presented herein. In all varieties mentioned, the central florets are long-awned. The 6-rowed parents in all hybrids belonged to the botanical variety *H. vulgare pallidum*, and include Manchuria, S. P. I. No. 20375, Sex-radigt, Odessa, Reid Triumph, Surprise, and a hybrid 6-rowed × 2-rowed barley. The lateral as well as the central florets of these varieties are long-awned and produce well-developed kernels.

The 2-rowed parents all belong to the variety *H. distichon palmella*. The central florets are long-awned, while the lateral ones are awnless with rounded tips and are sterile. Of the varieties mentioned in the text, Svanhals, Garton, and Primus belong to this group. The intermediates are products of hybridization, and the selections are unnamed. All, however, belong to the botanical variety *H. intermedium haxtoni*. In these the central florets are long-awned and produce normal kernels, while the lateral florets are awnless, as in the 2-rowed barleys, but fertile, producing undersized but viable kernels. The percentage of fertility in these spikelets is not so high as in the 6-rowed, but neither are they infertile, as are the 2-rowed. This form, obviously intermediate in character between the 6-rowed and 2-rowed barleys, has proved to be constant and is as distinct in its genetic behavior as either the 6-rowed or the 2-rowed forms.

The history of the intermediate barleys is very interesting, but not always clear. The first recorded observation found is that of John Haxton (*3*) in Scotland. In Morton's Cyclopedia of Agriculture of 1851 he mentions having observed such a plant in a field of "Bere." At the time

[1] This paper is based upon experiments conducted cooperatively by the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, and the Minnesota Agricultural Experiment Station.

[2] Reference is made by number (italic) to "Literature cited," pp. 590–591.

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of this description he obviously had the heterozygous intermediate or a mixture of this and the homozygous intermediate, since he obtained all types from the seeding. Later, the homozygous form seems to have been isolated. In 1883, Drechsler of Göttingen sent Rimpau an intermediate which he had found in a field of *H. distichon palmella zeocriton* and which apparently bred true from the time of its discovery. Both Rimpau (*6*, 7) and Körnicke (*4*) observed the intermediate. According to Körnicke's statement of 1885, he found the intermediate as an accidental hybrid in a field of 2-rowed winter barley. At first the selection was heterozygous, but, according to the statement of his son (*5*), in 1908, it later became constant. Both Rimpau and Körnicke made mass selections which evidently included heterozygous forms, at least at first. It is probable that homozygous types were eventually obtained.

These four cases of probable isolation of the fixed intermediate all occurred before 1900 and, therefore, before the importance of plant selections in hybrids was generally recognized. It is worthy of note that all four were instances where accidental hybrids were observed, rather than the products of any of the numerous crosses made by those investigators.

The history since 1900 is more surprising than that previous to 1900. The modern methods of breeding lead to the direct and ready isolation of this type, yet, so far as the authors know, it has not been reported. Since 1900, indeed, two plant breeders who have worked extensively with barley have assumed that a fixed intermediate does not occur in crosses between 6-rowed and 2-rowed barleys. Von Tschermak (*8*) says as late as 1914 that the intermediate form with fertile lateral florets is heterozygous and, therefore, is never constant. Biffin (*1*), while not so sweeping in his statement, must have held a similar view. In 1907, he reported nine crosses in which a homozygous intermediate might occur. From the F_2 progeny of one of these he selected a considerable number of intermediates of two types and planted them. All proved to be heterozygous. He did not test the progeny of the other crosses but assumed that they would behave in the same way. In the discussion he then states:

> The heterozygote, therefore, of forms with hermaphrodite staminate lateral florets is potentially hermaphrodite and of the type known to systematists as *H. intermedium*.

In 1907 J. H. Wilson (*9*) reported an F_2 generation of Standwell × Bere, in which he made the following observation:

> Examples occurred in which the grains of all six rows were fully developed, but the lateral ones were without awns.

In this case Mr. Wilson probably noticed the homozygous type. It is interesting that he should have used as the 6-rowed parent the variety of barley in which Haxton found the first recorded intermediate.

The observations of the senior author in these studies extend over the past 10 years. In the summer of 1909 he made a large number of hybrids on the grounds of the Minnesota Agricultural Experiment Station. A con-

siderable number of these were between 2-rowed and 6-rowed parents. In 1910 the F_1 generation was grown, and in 1911 the F_2 generation. In the F_1 generation of 1910 the heterozygous intermediate was very vigorous, and a considerable number of selections were grown in 1911 from the small lateral kernels to see if they would produce vigorous plants. In the F_2 generation it was apparent that there were intermediates present which differed from those of 1910, and 56 selections of different types of intermediates were grown in 1912. These came from 12 different crosses and included the progeny of combinations of 10 different 2-rowed and 7 different 6-rowed parents. A number of these proved to be homozygous, and others were isolated from the F_3 generation by further selection. Unfortunately, the records of 1912 are incomplete, and the total number of homozygotes obtained can not be determined. It is also impossible to establish the complete list of crosses from which fixed intermediates were obtained. Beyond all question, from one to five fixed intermediates were obtained from each of five different crosses. These crosses involve three different 2-rowed and five different 6-rowed parents. In these cases original material or complete records of the progeny are still at hand. The crosses were as follows: S. P. I. No. 20375 × Svanhals, Surprise × Primus, Primus × (2-rowed × 6-rowed), Garton 2-rowed × Sex-radigt, and Manchuria × Svanhals. There is a definite statement in the field records that a selection of *zeocriton* × Manchuria and another of Chevalier × South African were fixed intermediates, but there are neither specimens nor progeny records to confirm these statements.

It will be seen that in the five crosses where the evidence is complete the 2-rowed parents were dense-spiked. Aside from the fact that those which have been preserved came from such crosses, there is no evidence in the data now at hand that indicates inability to secure intermediates from crosses in which both parents are lax-spiked. The common varieties of lax 2-rowed barleys have less vigorous lateral florets than the common varieties of dense 2-rowed barleys. It is possible that the progeny of crosses where the lax forms were used would be lower in fertility and the intermediates correspondingly less conspicuous. Hence, they would be less desirable and less likely to be retained as specimens.

In 1915, after the junior author became connected with the Minnesota Agricultural Experiment Station, it was decided to repeat one of the crosses from which fixed intermediates had been secured, in order to determine the inheritance and, if possible, to discover an explanation of the occurrence of this form. By making crosses and growing an occasional generation in the greenhouse in Washington in the winter and sowing the seed in Minnesota in the spring several generations have been studied since that date. The cross chosen for this purpose was Manchuria × Svanhals. The F_2 and F_3 generations are reported in detail. Other crosses were studied in which no intermediates were produced; but since the data are negative, they have not been included,

although reference is made in the discussion to them and their significance.

OCCURRENCE OF H. INTERMEDIUM AND OTHER SEGREGATES IN THE PROGENY OF A CROSS OF MANCHURIA AND SVANHALS BARLEYS

The Manchuria parent in this cross is a selection of the common 6-rowed barley of the northern Mississippi Valley. The side florets are fertile and long-awned. The Svanhals parent is a well-known 2-rowed variety with long-awned, fertile, central florets and awnless, rounded, sterile lateral ones. The Manchuria is illustrated in Plate 103, C, and the Svanhals in Plate 104, A. This cross was made in the Washington greenhouse in the spring of 1917, and the F_1 generation was grown the same season at the University of Minnesota. In the fall of 1917, 100 of these F_1 seeds were sown in pots in the Washington greenhouse. Of these, only 87 matured as F_2 plants in the spring of 1918. As soon as the grain was sufficiently mature to harvest seed was again sent to Minnesota, where the F_3 generation was grown.

PHENOTYPIC CLASSES IN THE PROGENY

The data on the F_3 generation are reported in Table I, which needs considerable explanation. In the first place, the material itself is not simple. It is far from easy for a reader unfamiliar with barley to visualize six classes of segregates. Added to this difficulty is the fact that the F_3 classifications are of varying accuracy and are phenotypic in character. The phenotypic classes of the table give a misleading impression by overemphasizing the importance of the amount of fertility present. There are other characters than fertility which have much significance in the genetic groups. Fertility, however, is a definite, tangible, measurable condition, and the phenotypic classes founded on it are usable. In some instances the phenotypic classes of the F_3 generation coincide with the genetic classes, while in others a phenotypic class contains more than one genetic class. There is a certain amount of unavoidable confusion in describing both phenotypic and genetic classes at the same time. For this reason, until the genetic classes are established the plants exhibiting similar phenotypic classes in their progeny are placed together and referred to as genetic groups. It must be remembered in studying the table that the main object of the F_3 classification was to determine the genetic classes of the F_2 generation. It is well also to recall at this time that all classifications in this paper are based on the nature of the lateral florets, and to avoid endless repetition the modifying adjective is frequently omitted. In such cases the terms sterile, awn-pointed, high fertility, etc., refer to the lateral florets only.

Table I represents the data as taken. The first two columns of the table contain the identification numbers and the description of the F_2 plants. In the remaining columns the F_3 progeny of these plants are classified. These progeny fall into two major divisions, in one of which

all the kernels are of normal size, while in the other they are subnormal or absent. This second division is separated into plants which have lateral florets with awned or awn-pointed lemmas and plants in which the lemmas of the lateral florets are awnless and more or less rounded. Further subdivisions were based on the percentage of fertility of the lateral florets. The nature of the six resulting classes is illustrated in Plates 103 and 104. It is readily apparent in Plate 10£ that the three classes with awned or awn-pointed lemmas on the lateral florets are easily separated. It is just as apparent in Plate 104 that the accident of season or nutrition can easily affect the classification of the segregates with rounded lemmas. Errors of classification in this case happen to be unimportant, for, as previously stated, the object of the F_3 classification is only to determine the nature of the F_2 parent. This is made evident in all cases by the classification used. To make this clear, one of the findings must be anticipated. Of the six classes in which the F_3 plants are divided, three are of special importance in the interpretation. These are the fully fertile long-awned, the high-fertility awnless, and the no-fertility awnless classes. These represent the 6-rowed, the *intermedium*, and the 2-rowed barleys. In all cases the classification is sufficiently accurate to determine which of these classes are to be found in the progeny of each F_2 plant.

TABLE I.—*Classification of 87 F_2 plants and their F_3 progeny in a cross between Manchuria and Svanhals barleys according to the nature of their lateral florets*

GROUP 1, PLANTS WHICH GAVE ONLY 6-ROWED PROGENY

F_2 parent No.	F_2 parent type.	Number of individuals in F_3 progeny, by classes.						Total.
		Kernels normal size, lemmas long-awned, fully fertile (6-rowed).	Kernels subnormal in size or absent.					
			Lemmas awned or awn-pointed.		Lemmas awnless.			
			High fertility (80–100 per cent).	Low fertility (0–79 per cent).	Fertility 5–100 per cent (*intermedium*).	Fertility less than 5 per cent.	Fertility none (2-rowed).	
2	6-rowed	20						20
7	do	24						24
11	do	20						20
13	do	21						21
23	do	19						19
33	do	24						24
38	do	20						20
41	do	45						45
44	do	23						23
45	do	19						19
49	do	21						21
50	do	20						20
60	do	44						44
70	do	23						23
72	do	22						22
75	do	18						18

TABLE I.—*Classification of 87 F_2 plants and their F_3 progeny in a cross between Manchuria and Svanhals barleys according to the nature of their lateral florets*—Con.

GROUP 1, PLANTS WHICH GIVE ONLY 6-ROWED PROGENY—continued.

F_2 parent No.	F_2 parent type.	Number of individuals in F_3 progeny, by classes.						Total.
		Kernels normal size, lemmas long-awned, fully fertile (6-rowed).	Kernels subnormal in size or absent.					
			Lemmas awned or awn-pointed.		Lemmas awnless.			
			High fertility (80–100 per cent).	Low fertility (0–79 per cent).	Fertility 5–100 per cent (*intermedium*).	Fertility less than 5 per cent.	Fertility none (2-rowed).	
79	.....do.....	20	.....	.....	.....	.....	.....	20
82	.....do.....	45	.....	.....	.....	.....	.....	45
88	.....do.....	34	.....	.....	.....	.....	.....	34
94	.....do.....	21	.....	.....	.....	.....	.....	21
97	.....do.....	19	.....	.....	.....	.....	.....	19
100	.....do.....	15	.....	.....	.....	.....	.....	15
GROUP 2, PLANTS WHICH GAVE 6-ROWED AND INTERMEDIUM BUT NO 2-ROWED SEGREGATES								
29	80 per cent fertile, awned....	12	23	.....	12	.....	.....	47
62	25 per cent fertile, awned....	18	20	.....	6	.....	.....	44
64	90 per cent fertile, awned....	16	20	.....	10	.....	.....	46
85	33 per cent fertile, awned....	7	15	2	10	.....	.....	34
98	90 per cent fertile, awned....	17	13	.....	10	.....	.....	40
99	.....do.....	7	23	1	5	3	.....	39
37	5 per cent fertile, awnless....	7	30	.....	6	.....	.....	43
GROUP 3, PLANTS WHICH GAVE 6-ROWED, INTERMEDIUM, AND 2-ROWED SEGREGATES								
12	5 per cent fertile, awned.....	15	14	8	0	0	4	41
17	3 per cent fertile, awned.....	11	12	7	0	1	10	41
19	None fertile, awned.....	9	6	4	1	0	3	23
25	.....do.....	15	9	11	2	1	11	49
26	.....do.....	14	16	10	0	1	9	50
28	.....do.....	8	13	12	3	0	8	44
31	.....do.....	10	19	5	3	0	8	45
32	.....do.....	16	7	13	0	0	10	46
39	.....do.....	9	12	13	1	2	11	48
40	.....do.....	12	13	8	1	1	12	47
46	.....do.....	12	16	12	2	0	5	47
48	.....do.....	14	5	14	0	1	5	39
55	.....do.....	10	14	4	3	1	15	47
56	9 per cent fertile, awned.....	10	16	4	7	1	8	46
58	None fertile, awned.....	17	15	3	4	0	5	44
59	.....do.....	12	17	6	1	2	11	49
69	.....do.....	24	6	13	1	2	4	50
71	13 per cent fertile, awned....	13	6	3	1	0	3	26
74	12 per cent fertile, awned....	10	22	0	0	4	8	44
76	None fertile, awned.....	11	8	15	1	3	7	45
77	.....do.....	9	6	14	1	1	8	39
78	.....do.....	11	1	13	1	0	19	45
81	.....do.....	16	7	16	1	0	7	47
84	.....do.....	15	11	11	1	0	6	44
96	.....do.....	7	10	15	0	0	10	42

TABLE I.—*Classification of 87 F_2 plants and their F_3 progeny in a cross between Manchuria and Svanhals barleys according to the nature of their lateral florets*—Con.

GROUP 4, PLANTS WHICH GAVE 6-ROWED AND 2-ROWED BUT NO INTERMEDIUM SEGREGATES

F_2 parent No.	F_3 parent type.	Number of individuals in F_3 progeny, by classes.						Total.
		Kernels normal size, lemmas long-awned, fully fertile (6-rowed).	Kernels subnormal in size or absent.					
			Lemmas awned or awn-pointed.		Lemmas awnless.			
			High fertility (80–100 per cent).	Low fertility (0–79 per cent).	Fertility 5–100 per cent (*intermedium*).	Fertility less than 5 per cent.	Fertility none (2-rowed).	
9	None fertile, awned	5	.....	15	.....	.....	4	24
34	.....do	17	.....	19	.....	.....	9	45
35	.....do	6	.....	14	.....	.....	4	24
36	.....do	7	.....	26	.....	.....	11	44
47	.....do	11	.....	25	.....	.....	11	47
54	.....do	12	.....	25	.....	.....	10	47
65	.....do	13	.....	15	.....	.....	19	47
68	.....do	12	.....	16	.....	.....	15	43
83	.....do	7	.....	21	.....	.....	10	38
86	.....do	11	.....	19	.....	.....	13	43
GROUP 5, PLANTS WHICH GAVE ONLY INTERMEDIUM FORMS								
10	10 per cent fertile, awnless	.....	.....	.....	47	.....	.....	47
16	None fertile, awnless	.....	.....	.....	39	7	.....	46
18	.....do	.....	.....	.....	44	.....	.....	44
30	.....do	.....	.....	.....	41	5	.....	46
66	.....do	.....	.....	.....	38	.....	.....	38
93	.....do	.....	.....	.....	45	15	.....	60
95	20 per cent fertile, awnless	.....	.....	.....	35	.....	.....	35
GROUP 6, PLANTS WHICH GAVE INTERMEDIUM AND 2-ROWED BUT NO 6-ROWED SEGREGATES								
5	None fertile, awnless	.....	.....	.....	7	.....	40	47
6	.....do	.....	.....	.....	9	.....	38	47
14	.....do	.....	.....	.....	10	10	30	50
15	.....do	.....	.....	.....	8	9	24	41
24	.....do	.....	.....	.....	8	1	11	20
27	.....do	.....	.....	.....	6	4	36	46
42	.....do	.....	.....	.....	8	5	30	43
51	.....do	.....	.....	.....	12	3	33	48
67	.....do	.....	.....	.....	11	0	32	43
80	.....do	.....	.....	.....	4	0	42	46
92	.....do	.....	.....	.....	10	4	29	43
GROUP 7, PLANTS WHICH GAVE ONLY 2-ROWED FORMS								
4	None fertile, awnless	.....	.....	.....	.....	.....	46	46
8	.....do	.....	.....	.....	.....	.....	46	46
22	.....do	.....	.....	.....	.....	2	22	24
73	.....do	.....	.....	.....	.....	.....	45	45
89	.....do	.....	.....	.....	.....	.....	48	48

GENETIC GROUPS INDICATED BY THE PROGENY CLASSES

The F_2 plants in Table I are arranged in groups according to the segregation shown in the F_3 generation.

Group 1 consists of plants which gave only 6-rowed progeny in the F_3 generation. Since the parents were 6-rowed, the plants in this group are unquestionably homozygous for this character.

Group 2 consists of plants which gave 6-rowed and *intermedium* but no 2-rowed forms. The F_2 plants evidently correspond to those in the high-fertility column of the F_3 classification The classification of the high-fertility group is readily made and is highly accurate. Since this group gave 6-rowed, high-fertility, and *intermedium* segregates in approximately a 1 to 2 to 1 ratio, it is safe to assume that the high-fertility plants are heterozygous for 6-rowed × *intermedium* which differ by a single factor.

Group 3 gave all three homozygous classes and all heterozygous classes as well. From this it is obvious that this group is comparable to the F_2 generation and is heterozygous for the same factor differences as separate the original 6-rowed × 2-rowed forms.

Group 4 gave 6-rowed, low-fertility awned, and 2-rowed forms in approximately a 1 to 2 to 1 ratio. Since this low-fertility awned corresponded in appearance to the F_2 parents, it would seem that this group also was heterozygous for 6-rowed × 2-rowed, which in this instance, however, represents a single factor difference. It gave no *intermedium* forms, nor did it give the high-fertility awned or the low-fertility awnless forms. In other words, the *intermedium* character in both its homozygous and its heterozygous aspects was absent. The fact that this group as well as group 3 is heterozygous for 6-rowed × 2-rowed, even though more factors are involved in one case than the other, can be reconciled only on the basis that there are two types either of the 6-rowed or of the 2-rowed forms, only one of which carries the possibilities of producing *intermedium* forms.

Group 5 consists entirely of F_2 plants which gave only *intermedium* forms in the F_3 generation. In other words, out of 87 F_2 plants there were 7 homozygous for the the type which has been noticed so rarely in barley studies and whose very occurrence has been questioned so frequently. That the F_2 plants showed no higher fertility was doubtless due to their being grown in the greenhouse. Those plants of the F_3 generation falling in the low-fertility class merely show the variation which exists. They do not cast any doubt on the genetic character of the F_2 parents, because there were no 2-rowed segregates from any of the seven F_2 plants.

Group 6 gives homozygous intermediates, low-fertility awnless, and no-fertility awnless. The numbers in the classes are not significant in this case, for some sterile spikes of *intermedium* and the larger part of

one heterozygous group are included with the homozygous 2-rowed as phenotypes. The F_2 plants in group 6, however, unquestionably are heterozygous for *intermedium* × 2-rowed, a single main factor difference separating the *intermedium* and 2-rowed forms.

Group 7 may be considered as composed of plants homozygous for 2-rowed, since with the exception of the two plants noted there was no fertility exhibited in the progeny.

The seven groups just discussed consist of F_2 plants assembled in groups because of their evident similarity of genetic constitution. In other words, these groups are genetic classes in contradistinction to the phenotypic classes of the F_3 generation. In Table II the data on these groups are summarized. The second column of this table gives the genetic constitution of each group. Except for the subdivisions of group 1, this classification was verified in the F_3 generation. In the third column a hypothetical formula is suggested for each group. These formulas are based on a 2-factor difference between the 6-rowed and the 2-rowed forms. The Manchuria 6-rowed parent is supposed to possess both factors, while in the 2-rowed Svanhals parent both supposedly are lacking.

TABLE II.—*Summary of F_2 plants of the cross between Manchuria and Svanhals*

Group No. as in Table I.	Genetic constitution as shown by progeny.	Hypothetical formulas.	Expected Mendelian ratio.	Expected number on basis of 87 plants.	Number obtained in 87 plants.	Description of F_2 plants.
1	Homozygous for 6-rowed.....	AABB	1	22	22	Lateral florets long-awned, fully fertile, kernels normal size.
1	Heterozygous for 6-rowed × regressive 6-rowed.	AABb	2			
1	Homozygous for regressive 6-rowed.	AAbb	1			
2	Heterozygous for 6-rowed × *intermedium*.	AaBB	2	11	7	Lateral florets short-awned, highly fertile, kernels small.
3	Heterozygous for 6-rowed × 2-rowed.	AaBb	4	22	25	Lateral florets awn-pointed to short-awned, no fertility to low fertility.
4	Heterozygous for regressive 6-rowed × 2-rowed.	Aabb	2	11	10	Lateral florets awn-pointed to short-awned, no fertility.
5	Homozygous for *intermedium*.	aaBB	1	5	7	Lateral florets enlarged, awnless, low fertility to no fertility, kernels small.
6	Heterozygous for *intermedium* × 2-rowed.	aaBb	2	11	11	Lateral florets awnless, somewhat enlarged, no fertility.
7	Homozygous for 2-rowed.....	aabb	1	5	5	Lateral florets small, awnless, no fertility.

This hypothesis accounts for the results very well. The 2-rowed segregates of group 7 are homozygous in the absence of both factors. The fixed intermediates or *H. intermedium* forms of group 5 are homozygous for the presence of one factor and for the absence of the other. The heterozygous groups, 2, 3, 4, and 6, are all heterozygous for one or both factors. Groups 2, 4, and 6, which are heterozygous for only one factor, give F_3 progeny of limited distribution. Group 3, which is heterozygous for both factors, gives all classes in the F_3 generation.

Group 1 is the only group offering any complications, and these are of no particular complexity. If the 2-factor hypothesis is tenable, group 1 must include three different classes of 6-rowed forms, two of which are homozygous. If the factor AA is considered epistatic to the factor BB, the three classes of group 1 become phenotypic for 6-rowed and may be considered as a single class. In genetic constitution, however, the homozygous 6-rowed segregate AAbb differs from the parent 6-rowed AABB; and, inasmuch as the BB factor has been lost, the form AAbb is referred to here as a regressive 6-rowed. If this regressive 6-rowed AAbb were crossed on the Svanhals parent aabb, there would be no possibility of securing the homozygous intermediate aaBB. Heterozygous types corresponding to such a cross probably are found in group 4, which is supposed to be heterozygous for this regressive 6-rowed AAbb × the 2-rowed aabb. On the other hand, group 3 is heterozygous for the parent 6-rowed AABB × the 2-rowed aabb.

It will be seen in Table II that the plants obtained in each group came very close to the expectancy. The numbers of 6-rowed and 2-rowed forms produced coincide exactly with the expected numbers, while the number of fixed intermediates is only two greater than in the calculated ratio.

The nature of the factors is better discussed in connection with the description of the genetic classes which is given in Table II. It will be seen from the table that except in group 1 these various classes differ in appearance as well as in genetic constitution. In some instances the separations are easily made on appearance alone, while in others only a part of the plants belonging to a group can be easily identified. The first four groups have lateral florets, the lemmas of which bear awn points or awns of varying lengths. Group 1, of course, presents no difficulties, for 6-rowed segregates are unmistakable. Group 2 is almost as definite, for there are no other high-fertility segregates with small-kerneled, awn-pointed lateral florets. Group 3 is readily separated from group 2 by the lower fertility of the individuals in group 3. The sterile individuals of group 3, however, are easily confused with the individuals of group 4. Probably 80 per cent of such plants in group 3 can be identified by the more obtuse lemma tip on the lateral florets. Groups 5, 6, and 7 differ from the other groups in the absence of awns on the rounded tips of the lateral florets. These conditions are not absolute, in that an occasional floret may possess an awn. In this case, however, other florets on the same spike have the characteristic rounded obtuse tips. Group 5 is characterized by the possession of lateral florets which, even when sterile, are larger than those of the 2-rowed. Under field conditions higher fertility probably would have been present in the members of this group. When the F_2 material was being studied, it was possible, however, to isolate the sterile spikes of *intermedium* forms by inspection. In group 6 the lateral florets of many individuals are

obviously larger than in the 2-rowed segregates, but as a rule they are not so large as in group 5. Groups 6 and 7 can be accurately separated only by the breeding test.

It will be seen, then, that although fertility is the basic distinction, it is expressed in other ways than in the production or nonproduction of kernels. Indeed, the percentage of fertility probably varies more with environment than do the morphological differences. Such variation, however, does not imply any lack of reliability of the fertility factors.

According to the factor hypothesis, the first four groups have the inherent possibility of producing 6-rowed segregates. Only plants belonging to these four groups have lateral florets the lemmas of which are awned or awn-pointed. The A factor, either as AA or Aa, is found only in these groups. This factor, then, must be associated with the possibility of awns. When A is homozygous, fully fertile, long-awned florets which develop kernels of normal size are produced. When A is heterozygous, all lateral florets are short-awned or awn-pointed. When homozygous, it is epistatic to B, the spike being normal 6-rowed irrespective of the condition B. When heterozygous, A has little effect on fertility, and the amount of fertility present in this case is in direct relation to B. The lateral florets of AaBB are quite fertile, those of AaBb occasionally so, while those of Aabb as a class are sterile. Aa may have a slight effect on fertility, for AaBB has a higher percentage of fertility than aaBB. The factor BB, then, is a fertility factor which at its highest expression produces a lower percentage of fertility than AA. It is not accompanied by the presence of awns. The lateral florets under its stimulation produce undersized kernels, the largest form of floret seeming to be associated with AA.

INDICATION OF A THIRD FACTOR

The presence of a third factor of fertility was first suggested by a study of the data in Table I. Column 2 of that table shows the percentage of fertility of the F_2 parents. In group 2, three plants exhibited a much lower fertility than the other four. Since one of these was abnormal, there were, excluding this plant, two low-fertility and four high-fertility plants. It is difficult to measure the inheritance of these variations in this group. The percentage of fertility of the *intermedium* segregates in the F_3 generation of four lines was studied. The F_3 *intermedium* segregates of the others were missing. Three high-fertility lines gave almost identical fertility of 37+ per cent. One low-fertility line gave 29.5 per cent of fertility. In group 3, five out of twenty-five plants showed some fertility. The F_3 plants were not studied for differences in percentage of fertility.

In group 5, two out of seven plants had fertile lateral florets. In this group the progeny were studied carefully. This is the only group

where this can be done readily, because the others, where the differences in percentage of fertility occur, are heterozygous for one or both main factors. If there is a third factor, the F_2 generation indicates that it is expressed here as a 1 to 3 ratio with the heterozygous forms indistinguishable from those homozygous for the absence of the factor. By the same reasoning, lines 10 and 95 in Table I, which showed fertility, should be homozygous for the presence of the factor and should exhibit a higher percentage of fertility than the progeny of the other five lines. The F_3 progeny of lines 10 and 95 averaged 54.6 and 48.4 per cent of fertility in the lateral florets, while the progeny of the other lines were, respectively, 35.7, 33.2, 30.3, 25, and 17.8 per cent fertile.

The data indicating a third factor in fertility are summarized in Table III. The evidence at hand is not more than an indication of a minor factor, yet the material itself is far more suggestive of such a factor than the evidence.

TABLE III.—*Summary of data indicating a third factor of fertility in the cross between Manchuria and Svanhals*

Group No.	Genetic constitution as shown by progeny.	Hypothetical formulas.	Expected mendelian ratio.	Number of plants in group.	Expected number of plants by subgroups.	Number of plants obtained.
2	Heterozygous for 6-rowed × *intermedium*	AaBBCC	2	6	2	4
		AaBBCc	4		4	
		AaBBcc	2		2	2
3	Heterozygous for 6-rowed × 2-rowed	AaBbCC	4	25	6	5
		AaBbCc	8		13	20
		AaBbcc	4		6	
4	Heterozygous for regressive 6-rowed × 2-rowed	AabbCC	2	10	3	2
		AabbCc	4		5	6
		Aabbcc	2		3	2
5	Homozygous for *intermedium*	aaBBCC	1	7	2	2
		aaBBCc	2		4	5
		aaBBcc	1		2	

DISCUSSION OF RESULTS

FIXED INTERMEDIATE, H. INTERMEDIUM

Since the purpose of this study was to gain a better understanding of the occurrence of *H. intermedium*, this form is of greater interest here than any of the other segregates. From the standpoint of historical and present interest there are three questions which can now be answered. There is no doubt that such forms occur; they have been found to be stable; and in the particular cross reported here in detail the ratio of appearance is approximately 1 to 16.

The stability of this form was established by observations on intermediates obtained from several crosses. The field experiences fit in well

with the 2-factor hypothesis suggested. The stability of the homozygous intermediate has been thoroughly tested. Some of these have been grown since 1912 under widely varying conditions with no indication of reverting to either the 6-rowed or 2-rowed parental type. Many hybrids have been made with the *intermedium* form as one parent. There are complete records of the progeny of crosses on five 6-rowed and on two 2-rowed forms. No 2-rowed segregates appeared among the progeny of the 6-rowed × *intermedium* crosses, and no 6-rowed segregates appeared among the progeny of the *intermedium* × 2-rowed crosses. Every hybrid studied so far indicates that *H. intermedium* has a genetic rank equal to *H. vulgare* or *H. distichon*.

In field culture there is always variation in the amount of fertility present in the lateral florets of the *intermedium* form. This is true even on a single plant. The earlier, better-nourished spikes in some strains may have as high as 90 per cent of the lateral florets fertile. The later spikes of the same plant usually have a diminishing percentage, while the last-appearing may have lateral florets which are entirely sterile. Such variations, however, are the result of variation in nutrition, for their progeny are uniformly *intermedium* in type.

There are variations of another sort in the *intermedium* forms which have more significance. Frequent mention has been made of the fact that the fertility of the different classes may be expected to vary with the parents used. From crosses showing more vigor in the lateral florets of the segregates than those of the Manchuria × Svanhals, very vigorous intermediates may be isolated. From those crosses which show less fertility in the segregates, homozygous intermediates probably may be isolated in which only occasional kernels may be produced. Instances may be possible where a potential intermediate may exhibit no fertility whatever.

The form *atterbergii* shown in Plate 106 is probably an infertile *intermedium* barley. This form is somewhat anomalous in the taxonomy of barley. It has never been grown by the authors, but from the statements of those who have grown it, it appears to have shown no fertility. The illustration is a photograph of a spike presented to the United States Department of Agriculture several years ago by Mr. E. S. Beaven. It has greatly enlarged lateral florets which closely resemble those of spikes of *H. intermedium*, in which potentially fertile lateral florets are sterile because of environment.

REGRESSIVE 6-ROWED FORM

The recognition of the two different forms homozygous for the 6-rowed character offers a field for further investigation. The regressive 6-rowed AAbb is apparently not optically distinguishable from the AABB 6-rowed. There is no method known to the authors of separating these by inspection. In hybrids the regressive 6-rowed form should behave quite

differently. If this regressive type were crossed on the *intermedium* form the results, according to the hypothesis advanced, would not be the same as when the Manchuria is so crossed. The Manchuria × *intermedium* gives 6-rowed, high-fertility, and *intermedium* segregates in a 1 to 2 to 1 ratio in the F_2 generation. The regressive 6-rowed × the *intermedium* form should give all classes, including 2-rowed forms, in the F_2 generation. On the other hand, if the regressive 6-rowed were crossed on the Svanhals, no *intermedium* segregates would be expected. Unfortunately, neither of these crosses has been made, but the latter condition has been met in other crosses. Strains of Odessa and Reid Triumph when crossed on Svanhals produced no intermediates, indicating that the regressive 6-rowed AAbb does occur. The progeny of these crosses segregates in the same way as the group which is heterozygous for the regressive 6-rowed × 2-rowed in Table I. Incidentally, there is evidence that the strains used, of both Reid Triumph and Odessa, originated as selections from a previous hybridization. No evidence is at hand to indicate whether or not the regressive 6-rowed type AAbb occurs elsewhere than in the progeny of hybrids.

Because fixed intermediates have been secured from hybrids in which several old agricultural races of 6-rowed barley were used as one parent, it is assumed that forms such as the Manchuria are the normal 6-rowed forms. It is not known how frequently the regressive types occur among our agricultural sorts, nor whether they are associated with other characters than the failure to produce intermediates. Heritable variations in the amount of fertility in the lateral florets of 6-rowed barleys have been noticed, however, and since the conception of a regressive 6-rowed type offers a possible explanation of their behavior, a statement concerning these unusual varieties may be of interest.

In 1909 the senior author noticed a decided tendency to sterility of lateral florets in the agronomic varieties known as Mansfield and Summit. In each case the earliest spikes to appear were normal 6-rowed spikes. The lateral florets were highly fertile, long awned, and produced large kernels. In the later spikes, especially where the plants produced several culms, the lateral florets exhibited increasing sterility. Late spikes, in which none of the lateral florets were fertile, were found in many plants. One of these barleys, Mansfield, was the progeny of a cross between a 6-rowed and a 2-rowed barley, made at Guelph, Ont., in 1891. The peculiar behavior of this variety was so striking that selections of fertile and infertile spikes were made in 1909. These were planted in 1910, but, as would be expected, there was no difference in their inheritance. Owing to seasonal conditions the percentage of spikes with no fertility in the lateral florets was unusually large in 1910, the sterile spikes being approximately equal to the fertile in number. Spikes from a single plant are shown in Plate 105, D. It will be seen that the sterile florets are

long awned and that there is no approach toward the homozygous intermediate. The second variety, Summit, which for other reasons is thought also to be of hybrid origin, produced spikes with infertile lateral florets much more rarely. It is suggested that these barleys may be forms of the 6-rowed segregate AAbbcc, homozygous for the absence of the two secondary factors of fertility.

POSITION OF FERTILE LATERAL SPIKELETS

Aside from the question of the amount of fertility in the lateral florets, the location of fertile florets on the spike is of interest. In the common varieties of barley the largest kernels are produced about one-third of the distance from the base of the spike to the tip, in both the central and the lateral spikelets. The longest awns are attached to these florets, and they exhibit a progressive decrease in length toward the tip of the spike. The fertility of the homozygous intermediate runs in the reverse order. When only a few kernels are produced they are found in the upper third and gradually extend downward from the tip in the more fertile intermediates. The most fertile lateral florets in the Mansfield variety are found near the center of the spike.

ABERRANT LINE NO. 37

In Table I line No. 37 was found to differ greatly from the other members of group 2 in both appearance and fertility. It is much lower in fertility than the other individuals and, with the exception of one or two florets, is similar in appearance to the fixed intermediate. This plant is the only one of the 87 whose appearance is difficult to explain. It is not believed that the hypothesis of its being homozygous for the absence of the third factor is adequate explanation for its wide departure from type. For this reason this line was excluded in the later discussion. It is possible that the supposed F_2 plant is the result of a natural hybrid. The appearance of the forms in any class varies with the parents used. Some combinations result in greater fertility in the various classes, others result in much less. If the F_1 kernel from which this F_2 plant developed had been fertilized by some neighboring 6-rowed variety less vigorous than the Manchuria or by a low-fertility *intermedium* form, such a plant as No. 37 might result. The opportunity for accidental crossing in the F_1 generation is unusually good. The lateral florets of the F_1 plants are much more likely to open at flowering time than are the normal barley florets, and they flower after the spike is exserted. The flowering glumes are less interlocked and open more readily and more widely. The flowers are more frequently deficient in pollen, and those not self-pollinated remain open for hours or even days, affording unusual opportunity for cross pollination.

SUMMARY

H. intermedium is a form of barley in which the awnless lateral florets exhibit a fertility greater than that found in the 2-rowed and less than that occurring in the 6-rowed barleys.

The occurrence of this form as a homozygote has been questioned frequently.

H. intermedium forms which are stable under all conditions of culture have been isolated from numerous crosses reported in this paper. This form appears to be genetically as distinct as either *H. vulgare* or *H. distichon*.

A 2-factor hypothesis for fertility in the lateral florets is suggested. On the presence-and-absence hypothesis the 6-rowed barleys are supposed to be homozygous for the presence of the epistatic factor, the *intermedium* to be homozygous for the presence of the hypostatic factor and for absence of the epistatic factor, and the Svanhals to be homozygous for the absence of both factors.

According to the hypothesis, there are two types of 6-rowed barleys. The Manchuria parent is supposed to be homozygous for the presence of both factors, while certain regressive 6-rowed segregates are thought to be homozygous for the presence of the epistatic factor and for the absence of the hypostatic factor.

There is evidence suggestive of a third factor which affects the vigor of the lateral florets and their percentage of fertility.

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PLATE 103

Individual heads representing the three phenotypic progeny classes in which the lateral florets bear awns:

A.—Low-fertility class.

B.—High-fertility class.

C.—Manchuria parent representing the 6-rowed segregates.

A
B
C

A
B
C

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PLATE 104

Individual heads representing the phenotypic progeny classes in which the lemmas of the lateral florets are rounded and awnless:

A.—The 2-rowed, represented here by the Svanhals parent.

B.—Low-fertility class.

C.—*Hordeum intermedium*.

PLATE 105

A.—Awn-pointed individual, heterozygous for regressive 6-rowed and 2-rowed characters.

B.—Short-awned individual, heterozygous for regressive 6-rowed and 2-rowed characters.

C.—Long-awned individual, heterozygous for regressive 6-rowed and 2-rowed characters.

D.—Three spikes of Mansfield barley from the same plant, showing the variations of fertility in the lateral florets.

A
B
C
D

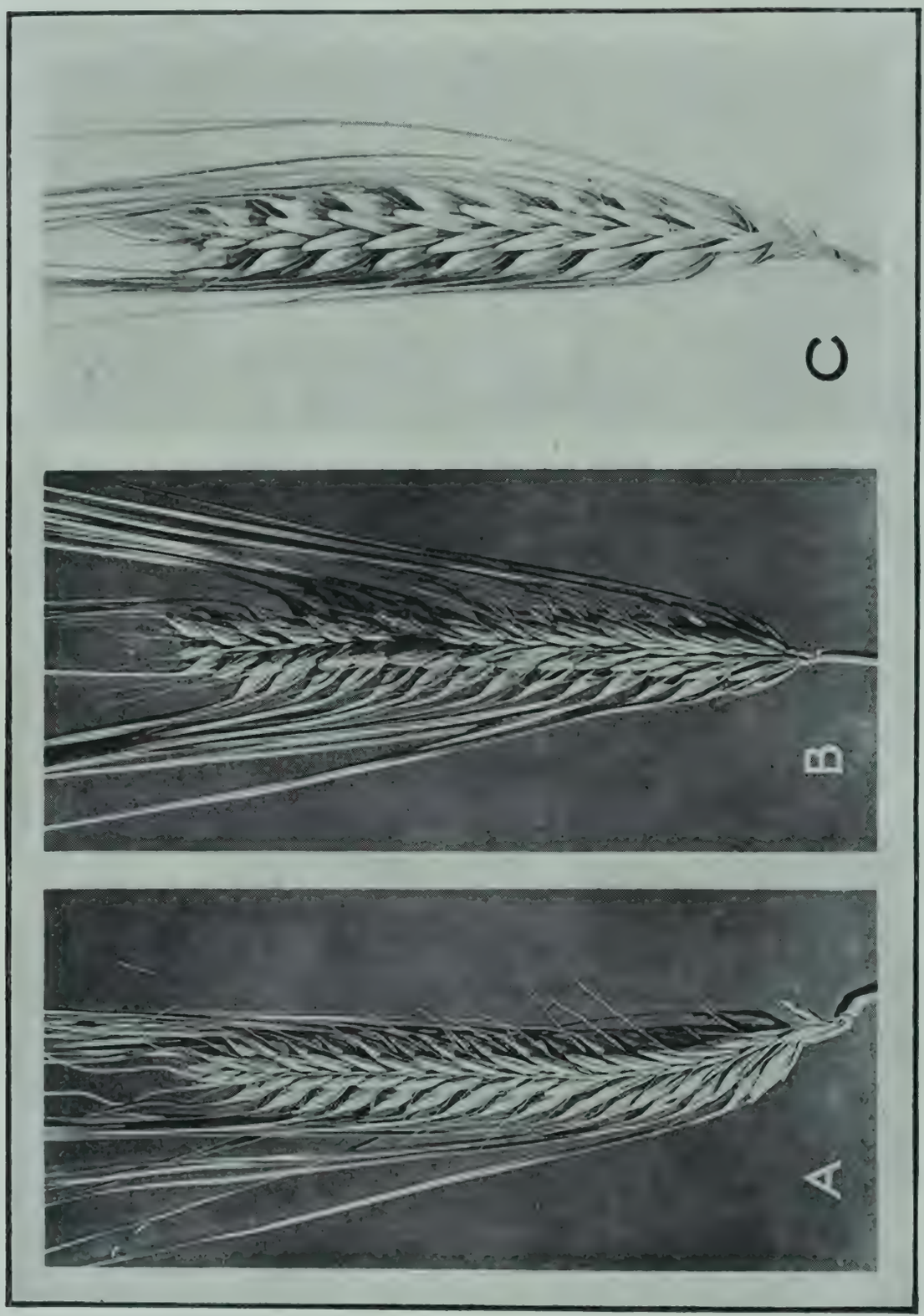
C
B
A

PLATE 106

A.—Infertile spike of potentially fertile *Hordeum intermedium*.
B.—Fertile spike of *H. intermedium*.
C.—Var. *atterbergii*, probably a sterile *intermedium*.

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